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ABSTRACT

This document describes the MASTER (Machine Tool Advanced Skills Educational Resources) program, a geographic partnership of seven of the nation's best 2-year technical and community colleges located in seven states. The project developed and disseminated a national training model for manufacturing processes and new technologies within the American machine tool industry. Goals of MASTER include the following: (1) assess instructional materials from an industry point of view; (2) design and develop a comprehensive series of instructional support materials with laboratory experiments specific to the machine tool and metals-related industries; (3) conduct pilot programs to evaluate content and effectiveness; (4) assess students at point of entrance and exit; and (5) compile and package project deliverables in CD-ROM format for national dissemination. This document contains the following: project methodology, development center profiles, pilot program descriptions and evaluations, acknowledgments, career enhancement and technical modules, career action plan model, job development center model, internship model, and industry training model. The modules and models each include an overview, descriptions, and specific information about its content. Three attachments contain sample materials from the Machining module, one of 11 technical modules developed by the project. (KC)

MASTER

a consortium of educators and industry

EDUCATIONAL RESOURCES FOR THE MACHINE TOOL INDUSTRY

Executive Summary

Supported by the National Science Foundation's Advanced Technological Education Program

MACHINE TOOL ADVANCED SKILLS TECHNOLOGY EDUCATIONAL RESOURCES

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National Science Foundation
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"Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Foundation."

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National Science Foundation - Division of Undergraduate Education
MASTER Consortia of Employers and Educators

MASTER has built upon the foundation which was laid by the Machine Tool Advanced Skills Technology (MAST) Program. The MAST Program was supported by the U.S. Department of Education - Office of Vocational and Adult Education. Without this prior support MASTER could not have reached the level of quality and quantity that is contained in these project deliverables.

<u>MASTER DEVELOPMENT CENTERS</u>
Augusta Technical Institute - Central Florida Community College - Itawamba Community College - Moraine Valley Community College - San Diego City College (CACT) - Springfield Technical Community College - Texas State Technical College

<u>INDUSTRIES</u>
AB Lasers - AIRCAP/MTD - ALCOA - American Saw - AMOCO Performance Products - Automatic Switch Company - Bell Helicopter - Bowen Tool - Brunner - Chrysler Corp. - Chrysler Technologies - Conveyor Plus - Darr Caterpillar - Davis Technologies - Delta International - Devon - D. J. Plastics - Eaton Leonard - EBTEC - Electro-Motive - Emergency One - Eureka - Foster Mold - GeoDiamond/Smith International - Greenfield Industries - Hunter Douglas - Industrial Laser - ITT Engineered Valve - Kaiser Aluminum - Krueger International. - Laser Fare - Laser Services - Lockheed Martin - McDonnell Douglas - Mercury Tool - NASSCO - NutraSweet - Rapistan DEMAG - Reed Tool - ROHR, International - Searle - Solar Turbine - Southwest Fabricators - Smith & Wesson - Standard Refrigeration - Super Sagless - Taylor Guitars - Tecumseh - Teledyne Ryan - Thermal Ceramics - Thomas Lighting - FMC, United Defense - United Technologies Hamilton Standard

<u>COLLEGE AFFILIATES</u>
Aiken Technical College - Bevil Center for Advanced Manufacturing Technology - Chicago Manufacturing Technology Extension Center - Great Lakes Manufacturing Technology Center - Indiana Vocational Technical College - Milwaukee Area Technical College - Okaloosa-Walton Community College - Piedmont Technical College - Pueblo Community College - Salt Lake Community College - Spokane Community College - Texas State Technical Colleges at Harlington, Marshall, Sweetwater

<u>FEDERAL LABS</u>
Jet Propulsion Lab - Lawrence Livermore National Laboratory - L.B.J. Space Center (NASA) - Los Alamos Laboratory - Oak Ridge National Laboratory - Sandia National Laboratory - Several National Institute of Standards and Technology Centers (NIST) - Tank Automotive Research and Development Center (TARDEC) - Wright Laboratories

<u>SECONDARY SCHOOLS</u>
Aiken Career Center - Chicopee Comprehensive High School - Community High School (Moraine, IL) - Connally ISD - Consolidated High School - Evans High - Greenwood Vocational School - Hoover Sr. High - Killeen ISD - LaVega ISD - Lincoln Sr. High - Marlin ISD - Midway ISD - Moraine Area Career Center - Morse Sr. High - Point Lamar Sr. High -

Pontotoc Ridge Area Vocational Center - Putnam Vocational High School - San Diego Sr. High - Tupelo-Lee Vocational Center - Waco ISD - Westfield Vocational High School

ASSOCIATIONS

American Vocational Association (AVA) - Center for Occupational Research and Development (CORD) - CIM in Higher Education (CIMHE) - Heart of Texas Tech-Prep - Midwest (Michigan) Manufacturing Technology Center (MMTC) - National Coalition For Advanced Manufacturing (NACFAM) - National Coalition of Advanced Technology Centers (NCATC) - National Skills Standards Pilot Programs - National Tooling and Machining Association (NTMA) - New York Manufacturing Extension Partnership (NYMEP) - Precision Metalforming Association (PMA) - Society of Manufacturing Engineers (SME) - Southeast Manufacturing Technology Center (SMTC)

MASTER PROJECT EVALUATORS

Dr. James Hales, East Tennessee State University and William Ruxton, formerly with the National Tooling and Machine Association (NTMA)

NATIONAL ADVISORY COUNCIL MEMBERS

The National Advisory Council has provided input and guidance into the project since the beginning. Without their contributions, MASTER could not have been nearly as successful as it has been. Much appreciation and thanks go to each of the members of this committee from the project team.

Dr. Hugh Rogers-Dean of Technology-Central Florida Community College
Dr. Don Clark-Professor Emeritus-Texas A&M University
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Mr. Robert Swanson-Administrator of Human Resources-Bell Helicopter, TEXTRON
Mr. Jack Peck-Vice President of Manufacturing-Mercury Tool & Die
Mr. Don Hancock-Superintendent-Connally ISD

SPECIAL RECOGNITION

Dr. Hugh Rogers recognized the need for this project, developed the baseline concepts and methodology, and pulled together industrial and academic partners from across the nation into a solid consortium. Special thanks and singular congratulations go to Dr. Rogers for his extraordinary efforts in this endeavor.

Dr. Don Pierson served as the Principal Investigator for the first two years of MASTER. His input and guidance of the project during the formative years was of tremendous value to the project team. Special thanks and best wishes go to Dr. Pierson during his retirement and all his worldly travels.

All findings and deliverables resulting from MASTER are primarily based upon information provided by the above companies, schools and labs. We sincerely thank key personnel within these organizations for their commitment and dedication to this project. Including the national survey, more than 2,800 other companies and organizations participated in this project. We commend their efforts in our combined attempt to reach some common ground in precision manufacturing skills standards and curriculum development.

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Manufacturing in Texas

Economic trends have led Texas officials to recognize the need to better prepare workers for a changing labor market. The downturn in the oil, natural gas, ranching and farming industries during the last decade diminished the supply of high-paying, low-skill jobs. Growth in Texas is occurring in the low paying, low skills service industry and in the high skills, high paying precision manufacturing industry. In Texas, projected increases by the year 2000 include 4,050 jobs for machine mechanics (24% growth rate); 4,700 jobs for machinists (18% growth rate); 3,850 numeric control operators (20% growth rate); and 107,150 general maintenance repair technicians (23% growth rate). The National Center for Manufacturing Sciences (NCMS) identified that of the top twenty manufacturing states, Texas experienced the largest increase in manufacturing employment. Manufacturing will add over 70,000 additional jobs in Texas by the year 2000 with increases in both durable and non-durable goods.

Texas State Technical College (TSTC)

Texas State Technical College System (TSTC) is authorized to serve the State of Texas through excellence in instruction, public service, research, and economic development. The system's efforts to improve the competitiveness of Texas business and industry include centers of excellence in technical program clusters on the system's campuses and support of educational research commercialization initiatives. Through close collaboration with business, industry, governmental agencies, and communities, including public and private secondary and postsecondary educational institutions, the system provides an articulated and responsive technical education system.

In developing and offering highly specialized technical programs and related courses, the TSTC system emphasizes the industrial and technological manpower needs of the state. Texas State Technical College is known for its advanced or emerging technical programs not commonly offered by community colleges.

New, high performance manufacturing firms in areas such as plastics, semiconductors and aerospace have driven dynamic change in TSTC's curriculum. Conventional metal fabrication to support oil and heavy manufacturing remains a cornerstone of the Waco campus and is a primary reason TSTC took the lead in developing new curricula for machining and manufacturing engineering technology in the MAST program.

Development Team

- **Principal Investigator**: Wallace Pelton served as the primary administrator and academic coordinator for the MASTER project.
- **Subject Matter/Curriculum Expert**: Steven Betros, Site Coordinator, was responsible for developing skill standards and course/program materials for the conventional machining, mold making and manufacturing engineering technology components of the MASTER project.

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PART ONE

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MASTER Executive Summary

Introduction

The past few years have seen vast amounts of discussion and money invested in skill standards. It seems that almost everyone agrees on the importance and relevance of skill standards, (in many cases these standards are already clearly defined for specific occupations and certain occupational clusters) yet the discussion, without action, continues. How much more time must be spent before we move on? How much more money do we have to spend before we move forward? The time has come for educators, business and industrial leaders, and governments to move on to the next step.

The intent of the proposals of the National Skill Standards Board is the establishment of a voluntary system which will guide the development and education of workers. Until these standards are in place, education and industry will continue doing as they have done since time immemorial—they will simply devise their own individual standards as the need arises. Superficially, this traditional system is capable of carrying us into the future; actually, American demographics are sounding the death knell of ad hoc standards.

In the Twentieth Century, science and technology progress at a rate unparalleled in history. The education of many workers is obsolescent even as they walk across the stage to receive their diplomas, outdated by the rapid pace of change in American industry. Looking back, American workers could once learn a set of skills and competencies which would carry them, with minor modifications, throughout their working lives. Not only did they work for the same employers for most of their careers, the influx of new technologies was slow enough that they could be re-educated on the job. Looking forward, American workers are faced with an increasingly rapid change in what they must know simply to retain their current positions. As companies embrace more and more new technology, many workers are forced out because the new technologies actually produce more with fewer workers. And these fewer positions go to those workers who are the best equipped with skills to operate and to maintain the new equipment. Those who cannot keep pace educationally are lost.

Technical educators are faced with the same dilemma. For many years, technical educators have been both comfortable and successful with teaching the same skills which had served them so well in their industries. Some technical educators have become intimidated; they actually feel that they are incapable of learning the new technologies well enough to teach them. More commonly, educators who cling to the old technologies attempt to justify their stance with this type of reasoning: No machinist can truly run a CNC lathe unless he fully understands and can operate the traditional engine lathe. As a result, many students who wish to enter technological careers are being taught inefficient and in utile skills. Therefore, not only is the older worker being left behind, the younger student is not even taken to the proper starting line! The student is left behind at the very beginning, innocently following the track laid out by the instructors, not realizing that this road leads nowhere.

Against this backdrop, American industry stands on the edge of international competition. Either we shall bridge this chasm with educated workers, or we shall find ourselves broken on its rocky bottom. Industry, education, and government must work in unprecedented cooperation to identify the skills and knowledge required by the modern world, and to establish the levels at which workers are expected to perform. Once this is accomplished, industry, unions, and educators will all work from the same blueprint. Industry will be assured of a competent workforce, whether from new hires of graduates or from the re-education of current workers. Educators will be assured that their teaching materials and methods are those which will truly prepare their students for the real jobs that exist in the workplace. New graduates, who once would have been forced to abandon their recently-chosen professions for different educational paths, will be assured that what they learn is what they need.

Without such a confluence of industry and education, guided by the government, the students who choose to follow careers in industry will surely abandon those careers. In addition, they will advise those younger than themselves that careers in industry are dead-ends and unfit to pursue under any circumstances. The pipeline of future workers will slowly run dry, leaving only a trickle to fuel the engines of American industry.

There is only one method by which American industry and education can avert the loss of workers. They must agree on which skills workers need, and at what level they must perform those skills. Whether this agreement leads to "Skill Standards" or "Performance Standards" is immaterial; industry and education have different names for the exact same thing! The first step has already been taken by the NSSB; now we must go on.

The second step is the embedding of those same skill standards into the educational establishment and its curricula. Educators must benchmark their programs to the national standards, and use these standards daily in their teachings. Only by such use can the educational community truly serve the needs of its students. Part of this process includes going to the local businesses and industries and asking a simple question: "What do you need?" While this may seem, at first glance, to be catering to the industries, it is, indeed, taking care of the needs of the students. An automotive mechanic cannot be expected to be hired as a maintenance electrician; how then, can we expect that undereducated students be hired at all?

Many skill standards projects have already clearly defined the skills and standards for several occupations, but this exercise is, in and of itself, relatively valueless. If the standards languish on bookshelves, in filing cabinets, and on CD-ROMs, then all the time and every cent of the money spent on identifying and quantifying them are utterly worthless. The payoff—the return to the taxpayer, to industry, and to education—comes only if the standards are implemented and used to help people better their lives. This includes not only the student, whose economic horizon is broadened extensively by a complete and modern education, but also industry, whose profits are enhanced by more skilled workers and lowered training costs.

The MASTER Program

There is a consortium of two-year technical colleges, supported by the National Science Foundation Division of Undergraduate Education, whose energies are already directed toward the implementation of skill standards. We have taken the currently-proposed standards of the metalworking occupations, such as the skill standards developed by the National Institute for Metalworking Skills (NIMS), put these standards into lesson plans and laboratory exercises, and put these plans and exercises to work. This consortium and its project are called the MASTER (Machine Tool Advanced Skills Educational Resources) Program. The ultimate goal of MASTER is the complete implementation of skills standards as described above, but its immediate goals include evaluating existing educational materials and programs for the machine-tool and metals-related industries, developing new materials and resources, and making these materials available to educators and industrialists throughout the United States.

Skill shortages in advanced skills technologies continue to severely limit the productivity of the American machine-tool industry and the problem is becoming more acute due to a new generation of equipment that requires a higher level of knowledge-based technicians. This national need necessitates the training of multi-skilled machine technicians capable of installing, integrating, maintaining, diagnosing, repairing, and modifying technologically advanced equipment systems. The survival of existing industries and the successful introduction of new manufacturing enterprises with advanced technologies require the development of innovative educational programs, new curricula, and improved methods.

The problems confronting industry in providing the training and education required for both entry-level and incumbent technicians include:

Use of outdated curricula by schools and colleges
The equipment evolution of the past five years has left curricula farther behind in metals and machining than in many other disciplines. Technicians are no longer conversational with the new equipment in their laboratories at work. Adaptive controls, artificial intelligence, rapid tool changing, in-process gaging, expanded communications with the factory floor, and conversational programming now allow technicians to determine the best way to get things done. Unfortunately, most technicians have not been prepared to solve problems at this level.

Low academic skill levels and the lack of employability skills

Previously, requirements for machine-tool technicians included mathematics and reading skills of at least the tenth-grade level. Now, college-level skills are needed. In addition to math and reading, the technician must have skills in science and communications. To supplement the academic skills, the technician must also have the proper work-readiness skills. These include a good work ethic, a positive attitude, punctuality, a desire to do the job right, common courtesy, social skills, and the ability to work with multi-skilled teams in a high performance workplace.

Lack of applicants for education in those skill areas that are critical to the success of the nation's industrial base

Post-secondary institutions and their industrial partners need to work more closely with public schools to give young people the vision and understanding of the opportunities and potential in the machine-tool and metals-related industries. Many students who might find these industrial careers attractive and fulfilling do not enter the fields simply because they do not know about them. Both industry and post-secondary institutions must reach out even further than they have before.

Education of technicians has not kept pace with the equipment evolution and new process capabilities

The efforts of both small and large manufacturers to produce products benchmarked to world-class standards have resulted in a rapid evolution in equipment design. This has necessitated and enabled new developments in multi-axis equipment with advanced controls and speeds of operation, severely challenging the capabilities of technicians. Plant managers are saying that new multi-task machine-tools are so advanced that even the expert workers cannot use the range of equipment capabilities. Educational institutions have not been immune to this, either. Many schools have been forced to close their obsolete programs.

Work-based training, apprenticeships, and internships do not truly integrate with education

Industry must be involved with education to ensure that, in work-based education, academic subjects closely match required skills. Work-based activities and internships have not usually been structured, well-defined, or measured by learning objectives and competencies. Current apprenticeship methods have major shortcomings that must be addressed in the school-to-work era.

Need for flexible training approaches that provide the proper learning tools for special populations and adult learners

Fundamental changes in training methods are required to meet the educational needs of women, minorities, immigrants, and disabled individuals who desire

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to enter the industry. Many training techniques appropriate for youth are not appropriate for adult learners. Special training programs are needed to serve the diverse individuals who will enter industry in the Twenty-First Century.

Aging of the skilled work force in machine-tool industries is reaching a stage of crisis for precision manufacturers
A tour of the Bell Helicopter TEXTRON plant in Dallas reveals a modern plant with six hundred machinists, but those machinists are, on average, fifty-five years of age. The plant manager wishes to hire one hundred qualified machinists in the next twelve months, but local programs have been closed. As a result, Bell Helicopter TEXTRON has become a major partner in project MASTER.

In response to these problems and concerns, MASTER has designed, developed, and will disseminate new curricular materials for Associate of Science, Associate of Applied Science, and Certificate degree options in the machining and metals-related technologies. These new materials are based on existing skill standards wherever possible. Since these occupational specialities generally require some form of external experiential based learning (i.e., co-ops, apprenticeships, or internships), the educational materials are designed and prescribed for use by industry in competency-based training programs, as well as traditional one- and two-year colleges.

MASTER has worked jointly with industrial and educational partners to create new learning programs which address the rapidly changing needs of the technology-driven machine-tool and metals-related manufacturing industry. The five key goals and the response to each of these goals are explained below.

Industrial Assessment
MASTER performed a comprehensive, industry-wide assessment of instructional materials needed to support present and future training needs, especially as they relate to increased productivity and enhanced global competitiveness. Particular emphasis was placed on the needs for structuring and enhancing apprenticeship activities that are extensions of post-secondary, experiential learning.

Educational Materials and Laboratory Materials
MASTER has designed and developed a comprehensive series of instructional support materials, with laboratory experiments and assessments specific to the machine-tool and metals-related industries, which is current with modern equipment and advanced and emerging technologies.

Pilot Program
MASTER has conducted a two-year pilot program with over four hundred selected applicants to evaluate the laboratory content of the materials and their effectiveness.

Student Assessment
All the students were tested at the point of entry for both theoretical and practical knowledge of their subjects. They were periodically evaluated throughout their attendance of the program, and were evaluated once more at their departure. A final evaluation, based on their work performance in industry, awaits.

Project Publications
MASTER is compiling and will package the program model on CD-ROM for national dissemination. The model includes course syllabi, references to required text(s), and instructor handbooks with lesson plans. Student laboratory handbooks with recommended laboratory equipment and experiments will be made separately available.

As previously mentioned, MASTER is a consortium made up of seven of the nation's best community and technical colleges, located in states housing one-third of the density of metals-related industries in the United States. These partner colleges have designed, developed, and tested the curricular materials. The MASTER development centers are:

Texas State Technical College - Waco, TX (lead);
Augusta Technical Institute - Augusta, GA;
Itawamba Community College - Tupelo, MS;
Moraine Valley Community College - Chicago, IL;
San Diego City College (CACT) - San Diego, CA;
Springfield Technical Community College - Springfield, MA; and,
Central Florida Community College - Ocala, FL.

MASTER has worked with many industry partners (many of whom are listed below) in the research, development, and validation of the project publications.

Bell Helicopter TEXTRON
Chrysler Technologies Airborne Systems
ALCOA
Lockheed Martin
NASSCO
Southwest Fabricators
McDonnell Douglas
Mercury Tool & Machine
Solar Turbines
D J Plastics
Foster Mold
Reed Tool
Laser Services, Inc.
National Oil Well
Tecumseh Products
Greco Systems
American Saw & Mfg. Co.
Fulghum Industries
Time Manufacturing
G&W Electric Company
MOOG Automotive
Teledyne Ryan Aeronautical
FMC Corporation
Andrew Corporation
Morrison Products
Texas Iron Works
Baker Oil Tool
Smith International.

MASTER also formed partnerships with the national laboratories, NIST centers, and other professional organizations, and worked closely with the following national skill standards projects (which were funded by the U.S. Department of Education and the U.S. Department of Labor):

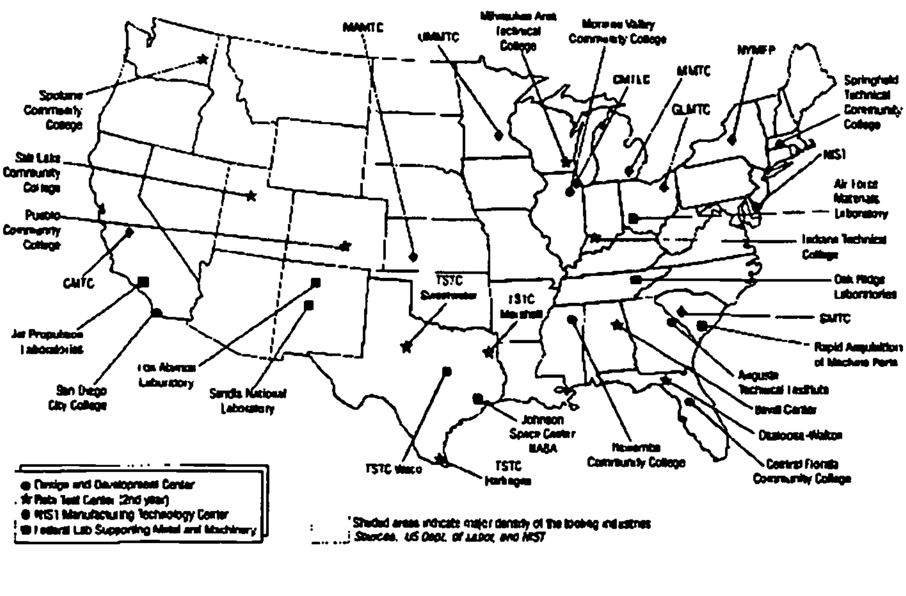
- Advanced High Performance Manufacturing - National Coalition for Advanced Manufacturing (NACFAM)
- Computer Aided Drafting and Design - National Coalition for Advanced Manufacturing (NACFAM)
- Metalworking - National Institute for Metalworking Skills (NIMS) in partnership with the National Tooling and Machining Association (NTMA)
- Welding - American Welding Society (AWS).

MASTER was charged with performing detailed job analyses and developing materials for the following metals-related occupations.

Manufacturing Technician	Advanced CNC and CAM
General Machinist	Instrumentation Technician
Industrial Maintenance Mechanic	Laser Machinist
Computer-Aided Drafting Technician	Mold Maker
Tool and Die Maker	EDM Technician
Automated Equipment Repair Technician	Welder

The map below will illustrate the geographical partnerships which made up MASTER.

MACHINE TOOL ADVANCED SKILLS TECHNOLOGY PROGRAM
EDUCATIONAL RESOURCES PROGRAM
(MASTER)



The Curriculum and Publications Resulting from the Work of Master Include the Following:

1. Remediation courses in basic skills for incumbent workers wishing to upgrade their job skills;

2. A career-orientation module (180 hours) for school-to-work participants;

3. General education courses in mathematics, statistics, geometry, physical sciences, physics, communications, reading, writing, and the social skills necessary for team building and problem solving;

4. Core courses in basic tools and machining principles, shop operations, machine blueprint reading, measurement tools, and quality principles;

5. Career enhancement and technical modules (180 hours) for use during the junior and senior high school years in basic machine-tool principals and practices;

6. **Advanced specialty area courses and models for the post-secondary level and competency-based training materials for each of the occupations listed above. Each technology comes with three different types of educational resources, with each type being bound separately. The three types of educational materials are:**
    a. **Course Syllabi for AAS and certificate programs,**
    b. **Instructor's Handbook (competency-based), and,**
    c. **Student Laboratory Manual (competency-based);**

7 An Industrial Training Model with educational materials, laboratory experiences, assessments, and certificates of competency for each technical specialty; and,

8. A "Concept for Career Action" Plan, a Job Development Center, a Career Orientation Module, and an Early Apprenticeship Model.

The MASTER publications will be compiled and packaged in both printed and multimedia forms for dissemination. The MASTER project staff will disseminate printed or multimedia materials to state, local, and national governmental, educational, and industrial organizations which have need for or interest in the MASTER materials. MASTER is also located on the Internet at http://machinetool.tstc.edu.

Conclusion

By getting the standards out of the library and into the lesson plan, off the shelf and into the student's hand, America will see a return on it's investment. Education is not about industry; it is about the people who make industry work. In some form or another, all these people begin their working lives as students. Whether they are educated by a technical school, by a university, by a huge international company, or by a small independent shop must be made irrelevant. Only national standards can achieve this goal, and only implemented, working standards can succeed.

In short, we as educators must move forward in three steps; we must:

1. Identify, quantify, and adopt the skills standards;
2. Recognize that these standards are useless until they are implemented; and,
3. Implant the standards in all aspects of the students' education.

If we as educators are not willing to do these three things, then let all the conferences and discussion cease, and let us redirect our money and our energy to some project that will be implemented to benefit people as individuals, by increasing their values in the workplace, by enhancing their opportunities, and by instilling in them the confidence of true education.

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MASTER - Project Methodology

Phase One - Research, Development, and Documentation

The Competency Profile

A large part of the work of MASTER was built on the research and documentation which was conducted and generated by the Machine Tool Advanced Skills Technology (MAST) Project. MASTER was designed and proposed as a follow-up to MAST. MAST was funded by the U.S. Department of Education, Office of Vocational and Adult Education (OVAE) and developed the skill standards and competency profiles from which MASTER based much of its work.

The project methodology was designed to build on the strength of the participating colleges' relationships with industry in order to ensure the relevance and credibility of the skills standards and model curricula. Given the compressed time frame for conducting the industry survey, it was agreed that the consortium partners would employ a modified version of the widely-used DACUM (Developing A Curriculum) process to identify the major types of skills required for employment in the occupational areas. This modified DACUM process resulted in a "Competency Profile" for each of the occupational specialties.

The Duties and Tasks, recorded on the Competency Profile, were identified by practitioners in the trade and are therefore "industry driven." A modified DACUM was performed at industry sites and facilitated by representatives of each development center. Panel members were identified on the Competency profile. Panel members were requested to identify job entry level skills and competencies, rank each Duty and Task, and identify the expected "sub-tasks" required to perform each Task within a given Duty. A complete list of industry generated Duties and Tasks has been prepared for each occupational specialty and entitled "Technical Workplace Competencies".

Additional skills for Mathematics, Science, and General Education courses were also identified by the panel members. The panel generated a list of "Skills and Knowledge", "Traits and Attitudes", and "Future Trends and Concerns" and are listed on the Competency Profiles.

Once final "industry validated" copy was secured, project personnel prepared extended course syllabi reflecting the industry's expectations of technical competencies, SCANS skills, and expected exit level proficiencies for each specific occupational specialty. Project personnel also developed competency-based training modules for each of the Duties and Tasks on all of the Competency Profiles.

It is this collection of Competency Profiles which is at the heart of every page of MASTER and the single most important component of the entire MASTER Program. These Competency Profiles provide a simple, straightforward communication tool for bringing together schools, colleges, and industry to work together in providing the training and education necessary for the high-tech jobs of the future.

The Competency Course Crosswalk

Once the Technical Competencies were identified, a "Technical Workplace Competency/Crosswalk" was prepared identifying each required course in the curriculum and the specific tasks which were taught in each respective course. An "Exit Proficiency Level Matrix" was developed for the Technical Workplace Competencies and each task was assigned an expected proficiency level at minimum performance level expectations of industry. The preparation of the "Technical Workplace Competency/Crosswalk" allowed faculty to review, modify, and adjust course syllabi to meet the expected exit level proficiencies.

This emphasis on competency-based training has led MASTER to find tremendous support from industry, labor, and those within the skill standards movement. Skill standards development projects generally follow either one of two basic approaches to documenting skill standards. One is referred to as the **skill components model** and the other as the **professional model**. These two models differ along two dimensions - the conceptualization of the skill and the role of workers in the development and governance of the standards system.

Professional Model: The performance and responsibilities of professional workers are not characterized by dividing their jobs into a list of discrete tasks or skills and then adding up tasks that the professional has mastered. The nuances of their roles and responsibilities make narrowly defined listings of their skills difficult to define. Generally, most require government and/or state certification boards and formal testing and experience duration requirements.

Skill Component Model: This model is based on the limited roles that front line workers are expected to carry out in traditional hierarchial organizations. Although this approach tends to focus on duties and tasks, and not on the work characteristics expected of an employee in a high performance organization, it is most often used by national pilot programs to document skills standards by occupation. This project used the Skill Components Model in its methodology. To help overcome the shortfalls of this model, soft skills were infused in the form of SCANS to ensure all the required skills were addressed.

The Scans/course Crosswalk

These soft skills are often referred to as advanced generic skills or SCANS skills (named after the U.S. Secretary of Labor's 1991 Commission on Achieving Necessary Skills). They are based on the recognition of the inadequacy of previous perspectives on skills. Although they differ from the skill components model, they do represent potential to expand the conceptualization of skills.

SCANS Competencies and specific classroom activities to address each SCANS Competency have been identified for each of the technical courses, the general education courses and the remediation courses and are included in the methodology.

The Industry Wide Assessment of Educational Resources

MASTER performed a comprehensive, industry-wide assessment of instructional materials needed to support present and future training needs, especially as they relate to increased productivity and enhanced global competitiveness. Particular emphasis was placed on the needs for structuring and enhancing internship and apprenticeship activities which are extensions of post-secondary, experiential learning.

Industry on-site visits involved a tour of facilities, review of pertinent job descriptions, and a modified DACUM process resulting in a Competency Profile for each occupational speciality. Employers and employees described expectations of worker skills, identified current required skills, and projected future trends. Employers in respective occupational specialties voiced their expectations for training of future employees.

Employers stated their expectations of any training programs and apprenticeships that could lead to employment within their company. Expectations for prerequisites and knowledge of math, sciences, and general education were also expressed fr each occupational speciality. Employers were presented with examples of the MASTER materials and asked to comment on the usefulness, ease of use, and potential benefit of the MASTER materials.

Once the project staff had developed several acceptable examples of instructional/training materials, a national survey was conducted. Over 2800 companies were surveyed concerning the format and content of the MASTER materials. With a six percent participation by the surveyed companies, project staff finalized these formats and resources and began preparing for the pilot programs which would be conducted at each of the participating institutions and participating companies.

PHASE TWO - Testing and Evaluation

The second phase of the project included curricula revisions by institutions and training providers and field testing of the revised curricula with students recruited as experimental groups.

MASTER conducted pilot programs at each partner college with over one thousand (total) selected applicants to evaluate the classroom and laboratory content of the materials and their effectiveness. Pilot programs were also conducted in cooperation with participating industries to evaluate the effectiveness of MASTER's materials for upgrade training with incumbent workers.

MASTER tested students enrolled in the pilot programs at point of entry for both theoretical and practical knowledge of their subjects. They were periodically evaluated throughout their attendance of the program and were evaluated once more at their departure from the program(s). Final evaluation, based on workplace performance, is an ongoing process and is an ongoing process.

Apprenticeship experiences were also defined and enhanced as part of the process. It is known that internships and apprenticeships currently lack definition and documentation of value-added experiences.

PHASE THREE - Production of Deliverables

MASTER designed and developed a comprehensive series of instructional support materials, with laboratory experiments and assessments specific to the machine-tool and metals-related industries. MASTER's training and educational resources are current with modern equipment and advanced and emerging technologies.

Once all formats and guidelines had been finalized by the project staff, these formats were approved by the MASTER National Advisory Council and the National Science Foundation.

Each MASTER development center undertook the huge task of developing the assigned course syllabi and technical training modules for their assigned specialty areas.

MASTER Project Deliverables

The following is a list of project deliverables which were promised in the original MASTER proposal, which was funded by NSF.

Remediation Courses in basic skills (reading, writing and math)

General Education Courses (which support the technical specialties)

Core Courses in basic tools and machining principles, shop operations, machine blueprint reading, measurement tools, and quality principles (imbedded in the technical specialties below)

Career Orientation & Technical Modules (180 hours) tailored for high school students in basic shop tools and machine practices

Technical Specialty Area Courses/Models and Competency-Based Technical Training Modules for the following occupational specialties:

- Automated Equipment Repair Technician (AET)
- Computer-Aided Drafting and Design Technician (CAD)
- Advanced CNC and CAM Technician (CNC)
- Industrial Maintenance Mechanic (IMM)
- Instrumentation Technician (INT)
- Laser Machinist (LSR)

- Conventional Machinist (MAC)
- Manufacturing Technician (MFG)
- Mold Maker (MLD)
- Tool and Die Maker (TLD) (includes EDM) (EDM)
- Welder (WLD)

Industrial Training Model which outlines the use of the MASTER technical modules for industrial training programs

Concept Documentation for Career Action Plan, Job Development Center, and Internship Model in support of school-to-work.

Deliverables Formats and Packaging
All Master deliverables have been disseminated by the following methods: Interactive CD-ROM and bound volumes

Interactive CD-ROM
All of the MASTER deliverables listed above have been included on the CD-ROM. The CD-ROM has been designed and formatted in such a way as to closely follow the organization of the printed materials described below.

Printed and Bound Volumes
MASTER deliverables have also be packaged and disseminated in hard copy. Because of the tremendous volume of these materials, these sets of printed materials have been used for **limited distribution only**. Sets of printed materials have been distributed to the National Science Foundation, all partner development centers and project evaluators.

MASTER partner colleges are also exploring ways of making printed sets of materials will also be made available, by special request, through some type of cost recovery process. Information about this request process may be obtained from our web site at ***http://machinetool.tstc.edu***. Printed volumes have taken the forms shown below:

EXECUTIVE SUMMARY containing the following:
1. Executive Summary
2. Project Justification and Methodology
3. Development Center Profiles
4. Acknowledgments

CAREER DEVELOPMENT containing the following:
1. Career Orientation and Technical Modules
2. Career Action Plan Model
3. Job Development Center Model
5. Internship Model
6. Industrial Training Model

REMEDIATION & GENERAL EDUCATION COURSES AND TECHNICAL MATHEMATICS MODULES containing the following:

1. Course Syllabi - Remediation Courses
2. Course Syllabi - General Education Courses
3. Technical Mathematics Modules

COURSE SYLLABI FOR EACH TECHNICAL SPECIALTY
Each technical specialty has a book which contains the following:

1. Introduction
   - Competency Profile
   - Curriculum and Course Descriptions
   - Technical Competency/Course Crosswalk (I, R, M)
   - SCANS
2. Individual Course Syllabi (by semester or quarter groupings)
3. Pilot Program Narrative

INSTRUCTOR HANDBOOKS FOR EACH TECHNICAL SPECIALTY
Each technical specialty has a book which contains the following:

1. Introduction
2. Individual Technical Modules (by "Duty" groupings)

STUDENT LABORATORY MANUAL FOR EACH TECHNICAL SPECIALTY
Each technical specialty has a book which contains the following:

1. Introduction
2. Individual Student Learning Modules (by "Duty" groupings)

ADMINISTRATIVE BOOK containing the following:

1. Annual Reports
2. Budget
3. Correspondence
4. Photos
5. Project Close-out

PHASE FOUR - Final Dissemination

MASTER compiled and packaged the program models on CD-ROM for national dissemination. The model includes course syllabi, references to suggested texts, instructor handbooks with competency-based training modules, and student laboratory handbooks with recommended laboratory equipment and experiments to over 1000 interested and participating schools, industries and governmental agencies.

Table of Contents

MASTER DEVELOPMENT CENTER, AUGUSTA, GA
Center for Advanced Technology
Augusta Technical Institute

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Terry Elam, President
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Manufacturing in the Augusta Region

Augusta is the second largest city in Georgia and manufacturing represents the largest sector of the Augusta economy. The region is home to 810 manufacturers employing 89,717 people, an industrial base consisting of about 75% process control and 25% discrete parts production facilities. Major areas of emphasis for industry include technology transfer, factory floor training, and job certification programs. Growth of manufacturing in the region has been driven by Augusta's high tech development in electronics, process control, telecommunications, computers, medical services and instrumentation.

Augusta Technical Institute and Center for Advanced Technology (CADTEC)

Augusta Technical Institute (ATI) is part of Georgia's Department of Technical and Adult Education system, serving a large percentage of the two-state Central Savannah River area through its main campus and satellite facilities. The student body includes vocational-technical and college prep students, as well as current workers seeking retraining or skills upgrade; ATI has long emphasized outreach and special attention to the needs of low income, rural and disadvantaged residents, as well as displaced workers, single parents, women in non-traditional fields, and the disabled. In 1983, the Institute used the opportunity to host one of Georgia's new regional advanced technology centers (ATC's) to streamline its technical programs and thereby help to ensure the future employability of its students. ATI's Center for Advanced Technology (CADTEC) is designed to provide technology research and demonstration, industry assessments, technical consulting, and industry-specific contract training for the many established and emerging high tech companies in the Augusta region.

Development Team

- **Project Director:** Mr. Ray Center, Director of CADTEC, served as program director for the MASTER project.
- **Subject Matter Expert**: Ronnie Lambert, MS, MASTER Site Coordinator, had program responsibility for developing skill standards based on the industry skills verification process, as well as developing course curricula and program materials for the MASTER pilot program in Industrial Maintenance Mechanic and Instrumentation Technician. Mr. Lambert has taught Industrial Maintenance Mechanic and Instrumentation for 32 years in colleges and industry across the Southeast.

MASTER DEVELOPMENT CENTER, OCALA, FL
Central Florida Community College

Central Florica Community College

Dr. Charles R. Dessance, President

Dr. Hugh Rogers, Project Administrator

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Manufacturing in Florida

During the past two decades, the Central Florida region near Florida's Space Coast, Melbourne, Cape Canaveral, Coala, Orlando, and the I-4 corridor to Tampa has experienced unprecedented economic growth. This growth has been especially evident in the fields of aerospace, electronics, laser electro-optics, and simulation enterprises. From 1990 to 1997 the area's population grew by more than 13 percent to approximately 4 million.

Manufacturing companies in the region now number more than 3000. The products manufactured range from aerospace to space launch equipment, advanced technology emergency vehicles, to sophisticated electronic and simulation components, circuit boards, laser equipment, wireless data systems, communication devices, and metals fabrication. Much of the nation's aerospace, satellite, and space facilities are concentrated in the region, including NASA, Lockheed Martin, E.G. and G. Inc., Boeing, McDonnell Douglas, Rockwell, Raytheon, Grumman, and Harris Corporation. Electronic companies such as Siemens, AT&T, Lucent, and Motorola serve both U.S. and export markets.

Central Florida, with three interstate highways (I-95, I-4, and I-75), is home to the University of Central Florida, its 27,000 students, and programs which include comprehensive engineering and engineering technology. Central Florida's growth has helped to fuel the State of Florida's growth to fourth largest state in the U.S. with a population of 14.6 million. By 2010 the state's population is projected to increase by more than 13 percent with 9 percent of its total workforce involved in manufacturing.

Central Florida Community College

Central Florida Community College (CFCC), serving a total of 6,000 students, offers a center of emphasis in Electronics, a Manufacturing Technology program with an internship requirement, an Industrial Maintenance/Machining program, a CADD program, and a Computer Design/Application program. Ocala, home of the college, has rapidly become an industrial center, with Lockheed Martin's Microelectronics Circuit Board Facility, and a second plant for Defense/Commercial Satellite Communications Manufacturing. E-One Corporation and other companies contribute to 17 percent of the local workforce being engaged in manufacturing.

Development Team

- **Project Coordinator**: Dr. Hugh Rogers, former Dean of Technical Education; served as the primary administrator and academic coordinator for the MASTER project. He also conducted the occupational skills profile interviews and benchmarked the welding instructional modules with review at four other colleges: Moraine Valley (Palos Hills, IL), IVY Tech (Terra Haute, Ind), Macomb Community College (Sterling Heights, MI), and Henry Ford Community College (Dearborn, MI).
- **Subject Matter** Experts: Mr Bill Rhodes and Mr Doug Wilson were responsible for developing skill standards and course/program materials for the welding technology components of the MASTER project. Other colleges and the American Welding Society.

MASTER DEVELOPMENT CENTER, TUPELO, MS
Itawamba Community College
Tupelo Campus

David Cole, President
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Manufacturing in Mississippi

Evolving from a previously agrarian economy, the region served by Itawamba Community College now contains a significant industrial base. Approximately 45% of employed adults in the surrounding area work in manufacturing, with the predominant industries including metal-working, machinery, paper products, rubber/plastics, electrical components, furniture, apparel, and wood products. About 35-40% of all manufacturing employees work in the furniture industry. After World War II, several major metal-working companies established branch plants in the Tupelo area, a trend that has continued into the 1990's. Between 1975 and 1980, pressures of competition and technology caused a number of these companies to reconsider their continued presence in northern Mississippi, spurring action by regional economic development organizations to preserve an employment and tax base essential to the community. Many of their economic development initiatives involved the community college, leading directly to the establishment of its Tool and Die Making Technology program and introduction of training in CAD, CNC, robotics, and lasers.

Itawamba Community College

Itawamba Community College (ICC) provides university transfer programs, associate degree career programs, non-credit customized industry training, and continuing education to a rural five-county area in northeast Mississippi. Of the local population of approximately 170,000 persons, 79% are white and 19% black; the student profile at the College roughly mirrors the racial composition of the general population, and a high percentage of students are from low-income households. The mission of the College includes the mandate to provide "educational services which contribute to the needs of new, expanding, or existing businesses and industries and to the training needs of the people." Accordingly, the College's instructional programs are designed with national trends and the needs of business and industry in mind, and the objective of all courses and training is to provide both students and companies with what they need to succeed. The main campus is in Fulton and the vocational-technical campus in Tupelo.

Development Team

- **Project Director:** Don Benjamin, Associate Dean of Career Education, served as program manager and academic coordinator for the MASTER project.
- **Site Coordinator**: Barry Emison was responsible for industrial assessment and skills validation, as well as development of skill standards and course/program materials for the Tool and Die Technology component of the MASTER project. Barry worked closely with Steve Zimmer of Syzygy, Inc., who conducted task analysis sessions with teams of expert workers.
- **Subject Matter Experts**: Pat Masur, Basic Skills/Related Studies Instructor, served as advisor for basic academic competencies, sharing responsibility with Mr. Emison for compiling data from industry surveys and interviews during the skill standards development process. Donald Taylor and Terry Kitchens, Tool and Die Technology Instructors, served as technical advisors for workplace competencies and developed course curricula and program materials. They also served as co-instructors and coordinators for the MASTER pilot program in Tool and Die Technology.

MASTER DEVELOPMENT CENTER, PALOS HILLS, IL
Center for Contemporary Technology
Moraine Valley Community College

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Manufacturing in Moraine Valley

The metropolitan Chicago area, including northwestern Indiana, is among the most heavily industrialized areas of the United States. The neighboring Moraine Valley area is home to hundreds of the small- to medium-sized companies that supply the larger industrial concerns, including design, fabrication, metal-working and parts-assembly firms. The diversity of industry in the region and the continual need for qualified entry-level technicians and retraining of current workers has created a great demand for the development of industrial training and the services of Moraine Valley Community College and its Center for Contemporary Technology.

Moraine Valley Community College (MVCC) and the Center for Contemporary Technology (CTT)

Moraine Valley Community College (MVCC) is a public, postsecondary institution serving all or part of 26 communities in the southwest suburban area of Cook County, representing a population of more than 380,000. Located 25 miles southwest of downtown Chicago in Palos Hills, the college is the fourth largest community college in Illinois and serves a diverse student body drawn from the surrounding communities. The focal point for business and industry training in Moraine Valley is the 124,000 s.f. Center for Contemporary Technology (CTT). Opened in 1988, the Center is among the finest and most diverse advanced technology centers (ATC's) in the nation, with over $6 million of equipment and technology to provide training and education in Automated Manufacturing; Automotive Technology; Computer-Aided Design; Electronics/Telecommunications; Environmental Control Technology; Information Management; Machining; Mechanical & Fluid Power Maintenance; Non-Destructive Evaluation; and Welding.

Development Team

- **Project Director**: Richard Hinckley, PhD., Dean of Instruction for Workforce Development and Community Services and manager of the Center for Contemporary Technology, served as director for the MASTER project.
- **Subject Matter Expert**: Charles H. Bales, Instructor of Mechanical Design/Drafting, had program responsibility for developing skill standards and course/program materials for the mechanical design/drafting component of the MASTER project. Professor Bales also served as lead instructor for the MASTER pilot program in Computer-Aided Drafting and Design (CADD) Technician.
- **Skills Validation Coordinator**: Richard Kukac, MPA, Associate Dean of Instruction of Business and Industrial Technology, coordinated the industry skills verification process for MASTER and facilitated the industry validation sessions with teams of expert practitioners from the skill area.

MASTER DEVELOPMENT CENTER, SAN DIEGO, CA
Center for Applied Competitive Technologies
San Diego City College

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Manufacturing in the San Diego Region

Manufacturing represents a major sector of the San Diego economy, accounting for almost one out of every four dollars (24%) of San Diego's gross regional product. The county is currently home to approximately 3,500 manufacturers employing roughly 110,000 San Diegans. During the first half of the 1990s, manufacturing in San Diego was hard hit by the downturn in military and defense spending which accompanied the end of the cold war. Many of the region's largest aerospace contractors rapidly downsized or moved their plants out of state, leaving a large supplier base that needed to modernize its manufacturing processes and convert to commercial markets. Rapid recovery of manufacturing in the region has been driven by San Diego's high tech research and development sectors in electronics, telecommunications, software, advanced materials, biotechnology, and medical instrumentation.

San Diego City College and its Center for Applied Competitive Technologies (CACT)

San Diego City College is an urban, minority institution, serving a large population of students from immigrant, disadvantaged, and low income households. In 1990, the College saw an opportunity to modernize its technical programs and improve the employment outlook for many of its students by agreeing to host one of the State of California's eight new regional manufacturing extension centers, the Centers for Applied Competitive Technologies (CACTs). The advanced technology centers were designed to assist local companies to modernize their manufacturing processes and convert from defense to newly emerging, technology-based commercial markets. This strategic partnership between the College and its resident CACT has proven to be highly successful. In developing the programs and lab facilities to serve the needs of regional manufacturing companies, the San Diego CACT and City College have simultaneously modernized the manufacturing and machine technology credit offerings of the College, thereby providing a well-trained, technically competent workforce for industry and enhancing career opportunities for students.

Development Team

- **Project Director:** Joan A. Stepsis, Ph.D., Dean/Director of the CACT-SD, served as programmatic manager and academic coordinator for the MASTER project.
- **Subject Matter Expert:** John C. Bollinger, Assoc. Prof. of Machine Technology, had programmatic responsibility for developing skill standards and course/program materials for the Advanced CNC and CAM component of the MASTER project. Professor Bollinger also served as the lead instructor for the MASTER instructional pilot for his specialty area.
- **Subject Matter Expert:** Douglas R. Welch, Assoc. Prof. of Manufacturing, had programmatic responsibility for developing skill standards and course/program materials for the Automated Equipment Technology (AET) and Machine Tool Integration (CIM) component of the MASTER project. Professor Welch also served as lead instructor for the MASTER instructional pilot for his specialty area.
- **Site Coordinator:** Mary K. Benard, MBA, CACT-SD Business/Operations Manager, coordinated the industry project activities for MASTER.

MASTER DEVELOPMENT CENTER, SPRINGFIELD, MA
Center for Business and Technology
Springfield Technical Community College

Dr. Andrew M. Scibelli, President
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Dr. Thomas E. Holland, Vice President
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Manufacturing in New England

According to a 1994 survey from the U.S. Bureau of Labor Statistics, approximately 17% of the employment in New England is manufacturing-related, 32% is service industry, 22% is trade industry, and 29% are other industries. Recent studies show that there are four major areas of emerging growth in technical employment: (1) telecommuncations, (2) biotechnology, (3) environmental technology, and (4) advanced manufacturing technology. Telecommunications, environmental technology and biotechnology are among the top four new growth industries of the region, now constituting a total of more than 205,000 new jobs (NEBHE, 1994). While manufacturing -- long a primary sector of the New England economy -- has declined in the post-cold war era, it still comprises roughly 20% of the employment base of the six-state region. The nature of manufacturing in New England, however, is changing in terms of the technologies of design and production, the materials used, and the products developed. The application of *photonics*, which includes laser machining, is a key emerging technology inherent in all four of the above industries.

Springfield Technical Community College and the Center for Business and Technology

Springfield Technical Community College (STCC) is a public post-secondary institution located within an hour's drive to over 750 metal-machining, optics and photonics manufacturing firms in Massachusetts and Connecticut. The only technical college among the fifteen community colleges in the Commonwealth of Massachusetts, the College is situated between two large urban, disadvantaged communities and serves a highly diverse student body: over 26% of its students are minority, 52% are female, and the average age of all STCC students is twenty-seven. STCC's Advanced Technology Center (ATC) has close to $8 million in technical facilities and equipment in the areas of laser-electro optics, electronics, mechanical technologies (CAD, CNC, CAM), computer-integrated manufacturing (CIM), environmental technology, and the most current computer hardware and software to support manufacturing-related training. STCC also employs a cadre of faculty experts in these technologies who enable the ATC to conduct industry assessments, technical consulting, and industry-specific contract training for the more than 300 small- and medium-sized companies throughout western Massachusetts and Connecticut. The majority of client companies are primary suppliers to the hundreds of defense contractors in New England, including such major firms as United Technologies, Pratt & Whitney, General Electric, Raytheon, and Lockheed-Martin.

Development Team

- **Project Director:** Thomas E. Holland, Ph.D., Vice President of the STCC Center for Business and Technology, served as overall director for the MASTER project.
- **Co-Project Directors**: Gary J. Masciadrelli, MSME, Department Chairman of the STCC Mechanical Engineering Technology Department, and Nicholas M. Massa, MSEE, Program Coordinator for the Laser Electro-Optics Technology program, shared programmatic responsibility for conducting industry assessment, designing curricula, administering the pilot program, and developing skill standards and course/program materials for the Laser Machining component of the MASTER project.

MASTER DEVELOPMENT CENTER, WACO, TX
Texas State Technical College

Dr. William Segura, Chancellor
Texas State Technical College System
Dr. Fred Williams, President
Texas State Technical College, Waco
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Manufacturing in Texas

Economic trends have led Texas officials to recognize the need to better prepare workers for a changing labor market. The downturn in the oil, natural gas, ranching and farming industries during the last decade diminished the supply of high-paying, low-skill jobs. Growth in Texas is occurring in the low paying, low skills service industry and in the high skills, high paying precision manufacturing industry. In Texas, projected increases by the year 2000 include 4,050 jobs for machine mechanics (24% growth rate); 4,700 jobs for machinists (18% growth rate); 3,850 numeric control operators (20% growth rate); and 107,150 general maintenance repair technicians (23% growth rate). The National Center for Manufacturing Sciences (NCMS) identified that of the top twenty manufacturing states, Texas experienced the largest increase in manufacturing employment. Manufacturing will add over 70,000 additional jobs in Texas by the year 2000 with increases in both durable and non-durable goods.

Texas State Technical College (TSTC)

Texas State Technical College System (TSTC) is authorized to serve the State of Texas through excellence in instruction, public service, research, and economic development. The system's efforts to improve the competitiveness of Texas business and industry include centers of excellence in technical program clusters on the system's campuses and support of educational research commercialization initiatives. Through close collaboration with business, industry, governmental agencies, and communities, including public and private secondary and postsecondary educational institutions, the system provides an articulated and responsive technical education system.

In developing and offering highly specialized technical programs and related courses, the TSTC system emphasizes the industrial and technological manpower needs of the state. Texas State Technical College is known for its advanced or emerging technical programs not commonly offered by community colleges.

New, high performance manufacturing firms in areas such as plastics, semiconductors and aerospace have driven dynamic change in TSTC's curriculum. Conventional metal fabrication to support oil and heavy manufacturing remains a cornerstone of the Waco campus and is a primary reason TSTC took the lead in developing new curricula for machining and manufacturing engineering technology in the MAST program.

Development Team

- **Principal Investigator**: Wallace Pelton served as the primary administrator and academic coordinator for the MASTER project.
- **Subject Matter/Curriculum Expert**: Steven Betros, Site Coordinator, was responsible for developing skill standards and course/program materials for the conventional machining, mold making and manufacturing engineering technology components of the MASTER project.

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This material was unavailable at the time of printing. Information concerning the pilot programs conducted by MASTER may be obtained by contacting the individual MASTER development centers.

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ACKNOWLEDGEMENTS

This project was made possible by the cooperation and direct support of the following organizations:

National Science Foundation - Division of Undergraduate Education
MASTER Consortia of Employers and Educators

MASTER has built upon the foundation which was laid by the Machine Tool Advanced Skills Technology (MAST) Program. The MAST Program was supported by the U.S. Department of Education - Office of Vocational and Adult Education. Without this prior support, MASTER could not have reached the level of quality and quantity that is contained in these project deliverables.

MASTER Development Centers

Augusta Technical Institute
Central Florida Community College
Itawamba Community College
Moraine Valley Community College
San Diego City College (CACT)
Springfield Technical Community College
Texas State Technical College

Industries

AB Lasers - ABB Power T&D Company, Inc., Distribution Systems Division - AIRCAP/MTD - ALCOA - American Saw - AMOCO Performance Products - Automatic Switch Company - Bell Helicopter - Bowen Tool - Brunner - Chrysler Corp. - Chrysler Technologies - Conveyor Plus - Darr Caterpillar - Davis Technologies - Dayco Products - Delta International - Devon - D. J. Plastics - Eaton Leonard - EBTEC - Electro-Motive - Emergency One - Entec, Inc. - Eureka - FMC, United Defense - Foster Mold - GeoDiamond/Smith International - Greenfield Industries - Hunter Douglas - Industrial Laser - ITT Engineered Valve - Kaiser Aluminum - Krueger International. - Laser Fare - Laser Services - Lockheed Martin - McDonnell Douglas - Mercury Tool - NASSCO - NutraSweet - Rapistan DEMAG - Reed Tool - ROHR, International - Searle - Solar Turbine - Southwest Fabricators - Smith & Wesson - Standard Refrigeration - Super Sagless - Taylor Guitars - Tecumseh - Teledyne Ryan - Thermal Ceramics - Thomas Lighting - Tombigbee Tooling - Tupelo Tool & Die - United Technologies Hamilton Standard

College Affiliates

Aiken Technical College - Bevil Center for Advanced Manufacturing Technology - Chicago Manufacturing Technology Extension Center - Great Lakes Manufacturing Technology Center - Indiana Vocational Technical College - Milwaukee Area Technical College - Okaloosa-Walton Community College - Piedmont Technical College - Pueblo Community College - Salt Lake Community College - Spokane Community College - Texas State Technical Colleges at Harlington, Marshall, Sweetwater

Federal Labs

Jet Propulsion Lab - Lawrence Livermore National Laboratory - L.B.J. Space Center (NASA) - Los Alamos Laboratory - Oak Ridge National Laboratory - Sandia National Laboratory - Several

National Institute of Standards and Technology Centers (NIST) - Tank Automotive Research and Development Center (TARDEC) - Wright Laboratories

Secondary Schools
Aiken Career Center - Chicopee Comprehensive High School - Community High School (Moraine, IL) - Connally ISD - Consolidated High School - Evans High - Greenwood Vocational School - Hoover Sr. High - Killeen ISD - LaVega ISD - Lincoln Sr. High - Marlin ISD - Midway ISD - Moraine Area Career Center - Morse Sr. High - Point Lamar Sr. High - Pontotoc Ridge Area Vocational Center - Putnam Vocational High School - San Diego Sr. High - Tupelo-Lee Vocational Center - Waco ISD - Westfield Vocational High School

Associations
American Vocational Association (AVA) - Center for Occupational Research and Development (CORD) - CIM in Higher Education (CIMHE) - Heart of Texas Tech-Prep - Midwest (Michigan) Manufacturing Technology Center (MMTC) - National Coalition For Advanced Manufacturing (NACFAM) - National Coalition of Advanced Technology Centers (NCATC) - National Skills Standards Pilot Programs - National Tooling and Machining Association (NTMA) - New York Manufacturing Extension Partnership (NYMEP) - Precision Metalforming Association (PMA) - Society of Manufacturing Engineers (SME) - Southeast Manufacturing Technology Center (SMTC)

Master Project Evaluators
Dr. James Hales, East Tennessee State University and William Ruxton, formerly with the National Tooling and Machine Association (NTMA).

National Advisory Council Members
The National Advisory Council has provided input and guidance into the project since the beginning. Without their contributions, MASTER could not have been nearly as successful as it has been. Much appreciation and thanks go to each of the members of this committee from the project team.

Hugh Rogers - Dean of Technology - Central Florida Community College
Don Clark - Professor Emeritus - Texas A&M University
Don Edwards - Department of Management - Baylor University
Jon Botsford - Vice President for Technology - Pueblo Community College
Robert Swanson - Administrator of Human Resources - Bell Helicopter, TEXTRON
Jack Peck - Vice President of Manufacturing - Mercury Tool & Die
Don Hancock - Superintendent - Connally ISD

Special Recognition
- Mr. Lucian Rouze (deceased) of Bell Helicopter, TEXTRON, played an important role in the formative months of MASTER. He served as a charter member of the National Advisory Council and his support, encouragement and guidance in the early days of MASTER are greatly appreciated by all who knew him.
- Dr. Hugh Rogers recognized the need for this project, developed the baseline concepts and methodology, and pulled together industrial and academic partners from across the nation into a solid consortium. Special thanks and singular congratulations go to Dr. Rogers for his extraordinary efforts in this endeavor.
- Dr. Don Pierson served as the Principal Investigator for the first two years of MASTER. His input and guidance of the project during the formative years was of tremendous value to the project team. Special thanks and best wishes go to Dr. Pierson.

All findings and deliverables resulting from MASTER are primarily based upon information provided by the above companies, schools and labs. We sincerely thank key personnel within these organizations for their commitment and dedication to this project. Including the national survey, more than 2,800 other companies and organizations participated in this project. We commend their efforts in our combined attempt to reach some common ground in precision manufacturing skills standards and curriculum development.

PART TWO

PART TWO

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Part One

Part Two

CAREER ENHANCEMENT
AND
TECHNICAL MODULES

Manufacturing Technologies Orientation

180 Hours of Career Enhancement and Technical Modules for the Precision Manufacturing Occupations

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Manufacturing Technologies Orientation

Total 180 Hours

Manufacturing Technologies Orientation

Graduating high school seniors are at a crossroads. Most assume that they have two basic options; enter the minimum-wage, service-providing marketplace or enter a four-year college for an engineering or business degree. Few take the time to consider a career as a technician in manufacturing technology.

Most have a picture of a dirty, dark plant doing one monotonous task all day long for their entire lifetime. They would be surprised to learn that the workplace is now clean and well lit with extremely sophisticated machines that require computer literate technicians, not operators, to produce a challenging part that takes a great deal of skill and knowledge. The machine tool industry has a large, documented shortage of these skilled technicians. Properly trained technicians earn more than the average four-year college graduate, and are in demand across the country.

A technician is a vital member of the overall engineering team involved in product design, testing, and manufacturing. The technician is a graduate of an accredited one-year certificate or a two-year associate degree program in a number of fields in the precision manufacturing industry ranging from a laser machinist to a tool and die maker. The technician has been thoroughly grounded in many of the same engineering fundamentals as engineering graduates, but in a more **applied manner**. Technicians use calculus and technical math, but they quickly see its practical application to the workplace and spend less time on theory.

Many graduating seniors choose not to go to college because they picture themselves being desk bound for life. They want "hands on" challenges. A career as a technician in the precision manufacturing industry provides the challenge, the income, and the opportunities to move up in the business.

This 180-Hour Career Enhancement and Technical Modules are designed to give the person at their crossroads in life an opportunity to review a career as a manufacturing technician. It is a self-paced, general instruction guide in basic shop tools and machining practices to give the student an opportunity to preview the field within this industry. Although self-paced, secondary schools should appoint a guidance counselor or shop instructor to help administer the program. The modules are designed around basic hand tools. No power tools or equipment is required. The program; however, could be modified to enhance the orientation if these are available. We would only add the precaution that a qualified instructor would be necessary if the program includes actual machine cutting, grinding, turning, or joining equipment.

This Basic Shop Tools and Machining Practices course serves as a portion of the MASTER deliverables. This course is designed as a career enhancement tool for high school students to be used in a self-paced instructional environment. The course content deals with topics of basic information on shop safety, mechanical hardware, reading drawings and materials used in machine tool practices. This course was developed by Machine Tool Advanced Skills Technology Educational Resources (MASTER) Program and any opinions, findings, conclusions, or recommendations expressed in this material are those of the MASTER consortium and do not necessarily reflect the views of the National Science Foundation.

Section A

Introduction

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Subject:

Section A --- Introduction

Objective:

After completing this unit, you should be able to identify the different career opportunities in machining and related areas.

In Order to Complete this Unit You Must:

1. Read Section A --- Introduction
2. Identify the professional machining career that would be of interest to you

Materials:

1. Student text

Length:

Approximately 2 hours

Section A

Unit 1, Shop Safety

Texts:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section A — Unit 1, Shop Safety

Objectives:

After completing this unit, you should be able to:

1. Identify common shop hazards; and,
2. Identify and use common shop safety equipment.

In Order to Complete this Unit You Must:

1. Read Unit 1, Shop Safety;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 1, Shop Safety.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 4 hours

Section A

Unit 2, Mechanical Hardware

Texts:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section A — Unit 2, Mechanical Hardware

Objectives:

After completing this unit, you should be able to:

1. Identify treads and threaded fasteners;
2. Identify tread nomenclature on drawings;
3. Discuss standard series of threads; and,
4. Identify and describe applications of common mechanical hardware found in the machine shop.

In Order to Complete this Unit You Must:

1. Read Unit 2, Mechanical Hardware;
2. Complete the Self-Test at the end of this unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 2, Introduction to Mechanical Hardware.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 8 hours

Section A

Unit 3, Reading Drawings

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section A — Unit 3, Reading Drawings

Objective:

After completing this unit, you should be able to read and interpret common detail drawings found in the machine shop.

In Order to Complete this Unit You Must:

1. Read Unit 3, Reading Drawings;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 3, Reading Shop Drawings.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 8 hours

Section B

Hand Tools

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Subject:

Section B — Hand Tools

Objective:

After completing this unit, you should be able to understand the importance of hand tools and their purpose

In Order to Complete this Unit You Must:

1. Read Section B — Hand Tools; and,
2 Understand the importance of hand tool safety.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text

Length:

Approximately 2 hours

Section B

Unit 1, Arbor and Shop Presses

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 1, Arbor and Shop Presses

Objectives:

After completing this unit, you should be able to:

1. Install and remove a bronze bushing using an arbor press;
2. Press on and remove a ball bearing from a shaft on an arbor press using the correct tools;
3. Press on and remove a ball bearing from a housing using an arbor press and correct tooling;
4. Install and remove a mandrel using an arbor press; and,
5. Install and remove a shaft with key in a hub using the arbor press.

In Order to Complete this Unit You Must:

1. Read Unit 1, Arbor and Shop Presses;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 1, Arbor and Shop Presses.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 12 hours

Section B

Unit 2, Work-holding and Hand Tools

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 2, Work-Holding and Hand Tools

Objectives:

After completing this unit, you should be able to:

1. Identify various types of vises, their uses, and maintenance;
2. Identify the proper tool for given job; and,
3. Determine the correct use of a selected tool.

In Order to Complete this Unit You Must:

1. Read Unit 2, Work-Holding and Hand Tools;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 2, Noncutting Hand Tools.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 6 hours

Section B

Unit 3, Hacksaws

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 3, Hacksaws

Objectives:

After completing this unit, you should be able to identify, select, and use hand hacksaws.

In Order to Complete this Unit You Must:

1. Read Unit 3, Hacksaws;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 3, Hacksaws.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 4 hours

Section B

Unit 4, Files

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 4, Files

Objectives:

After completing this unit, you should be able to identify eight common files and some of their uses.

In Order to Complete this Unit You Must:

1. Read Unit 4, Files;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 4, Files and Off-Hand Grinding.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 8 hours

Section B

Unit 5, Hand Reamers

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 5, Hand Reamers

Objectives:

After completing this unit, you should be able to:

1. Identify at least five types of hand reamers; and,
2. Hand ream a hole to a specified size.

In Order to Complete this Unit You Must:

1. Read Unit 5, Hand Reamers;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 5, Hand Reamers.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 8 hours

Section B

Unit 6, Identification and Uses of Taps

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 6, Identification and Uses of Taps

Objectives:

After completing this unit, you should be able to:

1. Identify common taps; and,
2. Select taps for specific applications.

In Order to Complete this Unit You Must:

1. Read Unit 6, Identification and Uses of Taps;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 6, Taps, Identification and Application.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 12 hours

Section B

Unit 7, Tapping Procedures

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 7, Tapping Procedures

Objectives:

After completing this unit, you should be able to:

1. Select the correct tap drill for a specific percentage of thread;
2. Determine the cutting speed for a given work material — tool combination;
3. Select the correct cutting fluid for tapping;
4. Tap holes by hand or with a drill press; and,
5. Identify and correct common tapping problems.

In Order to Complete this Unit You Must:

1. Read Unit 7, Tapping Procedures;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 7, Tapping Procedures.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 12 hours

Section B

Unit 8, Thread-cutting Dies and Their Uses

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 8, Thread-Cutting Dies and Their Uses

Objectives:

After completing this unit, you should be able to:
1. Identify dies used for hand threading;
2. Select and prepare a rod for threading; and,
3. Cut threads with a die.

In Order to Complete this Unit You Must:

1. Read Unit 8, Tread-Cutting Dies and Their Uses;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 8, Tread-Cutting Dies and Their Uses.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 10 hours

Section B

Unit 9, Off-hand Grinding

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section B — Unit 9, Off-Hand Grinding

Objectives:

After completing this unit, you should be able to describe setup, use, and safety of the pedestal grinder.

In Order to Complete this Unit You Must:

1. Read Unit 9, Off-Hand Grinding;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 9, Off-Hand Grinding.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 8 hours

Section C

Dimensional Measurement

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Subject:

Section C — Dimensional Measurement

Objectives:

After completing this unit, you should be able to:

1. Define measurement;
2. Identify some of the measurement needs of the Machinist;
3. Define metrology;
4. Define accuracy;
5. Define precision;
6. Define reliability;
7. What does discrimination refer to;
8. Define calibration;
9. Know what the common expression "the measurement is right on" means; and,
10. Identify ten measuring instruments that are available to a machinist.

In Order to Complete this Unit You Must:

1. Read Section C, Dimensional Measurement

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text

Length:

Approximately 4 hours

Section C

Unit 1, Systems of Measurement

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section C — Unit 1, Systems of Measurement

Objectives:

After completing this unit, you should be able to:
1. Identify common methods of measurement conversion; and,
2. Convert inch dimensions to metric equivalents and convert metric dimensions to inch equivalents.

In Order to Complete this Unit You Must:
1. Read Unit 1, Systems of Measurement;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 1, Systems of Measurement.

Materials:
1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 6 hours

Section C

Unit 2, Using Steel Rules

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section C — Unit 2, Using Steel Rules

Objectives:

After completing this unit, you should be able to:

1. Identify various kinds of rules and their applications; and,
2. Apply rules in typical machine shop measurements.

In Order to Complete this Unit You Must:

1. Read Unit 2, Using Steel Rules;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 2, Using Steel Rules.

Materials:

1. Paper
2. Pencil #2 or pen
3. Rule Measuring Kit
4. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 4 hours

Section C

Unit 3, Using Vernier, Dial, and Digital Instruments for Direct Measurements

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section C — Unit 3, Using Vernier, Dial, and Digital Instruments for Direct Measurements

Objectives:

After completing this unit, you should be able to:

1. Measure and record dimensions to an accuracy of plus or minus .001 in. with a vernier caliper;
2. Measure and record dimensions to an accuracy of plus or minus .02 mm using a metric vernier caliper; and,
3. Measure and record dimensions using a vernier depth gage.

In Order to Complete this Unit You Must:

1. Read Unit 3, Using Vernier, Dial, and Digital Instruments for Direct Measurements;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 3, Using Vernier Dial and Digital Instruments.

Materials:

1. Paper
2. Pencil #2 or pen
3. Inch Vernier Caliper Measuring Test Kit
4. Metric Vernier Caliper Measuring Test Kit
5. Inch Vernier Depth Gage Measuring Test Kit
6. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 12 hours

Section C

Unit 4, Using Micrometer Instruments

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section C — Unit 4, Using Micrometer Instruments

Objectives:

After completing this unit, with the use of appropriate measuring kits, you should be able to:

1. Measure and record dimensions using outside micrometers to an accuracy of plus or minus .001 of an inch;
2. Measure and record diameters to an accuracy of plus or minus .001 of an inch;
3. Measure and record depth measurements using a depth micrometer to an accuracy of plus or minus .001 inch;
4. Measure and record dimensions using a metric micrometer to an accuracy of plus or minus .01 mm; and,
5. Measure and record dimensions using a vernier micrometer to an accuracy of plus or minus .0001 in. (assuming proper measuring conditions).

In Order to Complete this Unit You Must:

1. Read Unit 4, Using Micrometer Instruments;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 4, Using Micrometer Instruments.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 8 hours

Section C

Unit 5, Using Comparison Measuring Instruments

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition
Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section C — Unit 5, Using Comparison Measuring Instruments

Objectives:

After completing this unit, you should be able to:

1. Define comparison measurement;
2. Identify common comparison measuring tools; and,
3. Given a measuring situation, select the proper comparison tool for the measuring requirement.

In Order to Complete this Unit You Must:

1. Read Unit 5, Using Comparison Measuring Instruments;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 5, Using Comparison Measuring Instruments.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 8 hours

Section C

Unit 6, Using Gage Blocks

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section C — Unit 6, Using Gage Blocks

Objectives:

After completing this unit, you should be able to:

1. Describe the care required to maintain gage block accuracy;
2. Wring gage blocks together correctly;
3. Disassemble gage block combinations and properly prepare the blocks for storage;
4. Calculate combinations of gage block stacks with and without wear blocks; and,
5. Describe gage blocks applications.

In Order to Complete this Unit You Must:

1. Read Unit 6, Using Gage Blocks
2. Complete the Self-Test at the end of the unit with 100% accuracy
3. Successfully pass the Post Test on Unit 5, Using Gage Blocks

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 6 hours

Section C

Unit 7, Using Angular Measuring Instruments

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Subject:

Section C — Unit 7, Using Angular Measuring Instruments

Objectives:

After completing this unit, you should be able to:

1. Identify common angular measuring tools;
2. Read and record angular measurements using a vernier protractor;
3. Calculate sine bar elevations and measure angles using a sine bar and adjustable parallels; and,
4. Calculate sine bar elevations and establish angles using a sine bar and gage blocks.

In Order to Complete this Unit You Must:

1. Read Unit 7, Using Angular Measuring Instruments; and,
2. Complete the Self-Test on page 195 with 100% accuracy.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text

Length:

Approximately 8 hours

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Section C

Unit 8, Tolerances, Fits, Geometric Dimensions, and Statistical Process Control (SPC)

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Subject:

Section C — Unit 8, Tolerances, Fits, Geometric Dimensions, and Statistical Process Control (SPC)

Objectives:

After completing this unit, you should be able to:

1. Describe basic reasons for tolerance specifications;
2. Recognize common geometric dimensions and tolerances;
3. Describe the reasons for press fits and know where to find press fit allowance information; and,
4. Describe in general terms the purpose of SPC.

In Order to Complete this Unit You Must:

1. Read Unit 8, Tolerances, Fits, Geometric Dimensions, and Statistical Process Control (SPC); and,
2. Complete the Self-Test at the end of the unit with 100% accuracy.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text

Length:

Approximately 10 hours

Section D

Materials

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Subject:

Section D — Materials

Objectives:

After completing this unit, you should be able to:

1. Identify the raw materials used in making iron and steel;
2. What are the two safety rules in lifting;
3. How is hot metal identified; and,
4. Why do you never look toward arc welding.

In Order to Complete this Unit You Must:

1. Read Section D, Materials

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text

Length:

Approximately 2 hours

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Section D

Unit 1, Selection and Identification of Steels

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section D — Unit 1, Selection and Identification of Steels

Objectives:

After completing this unit, you should be able to identify different types of metals by various means of shop testing.

In Order to Complete this Unit You Must:

1. Read Unit 1, Selection and Identification of Steels;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 1, Selection and Identification of Steels.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 4 hours

Section D

Unit 2, Selection and Identification of Nonferrous Metals

Text:

Machine Tool Practices, Kibbe, Neely, Meyer & White, Prentice Hall, Latest Edition

Instructor's Manual for Machine Tool Practices, Latest Edition

Subject:

Section D — Unit 2, Selection and Identification of Nonferrous Metals

Objectives:

After completing this unit, you should be able to:

1. Identify and classify nonferrous metals by a numerical system; and,
2. List the general appearance and use of various nonferrous metals.

In Order to Complete this Unit You Must:

1. Read Unit 2, Selection and Identification of Nonferrous Metals;
2. Complete the Self-Test at the end of the unit with 100% accuracy; and,
3. Successfully pass the Post Test on Unit 2, Selection and Identification of Nonferrous Metals.

Materials:

1. Paper
2. Pencil #2 or pen
3. Student text and *Instructor's Manual for Machine Tool Practices,* Latest Edition

Length:

Approximately 4 hours

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Table of Contents

Career Action Plan Model

Overview

A career action plan serves as a roadmap that outlines the methods and procedures one might follow in developing a career path in a particular area. It incorporates one's total personal interest and aptitude, and includes external factors which influence decisions in a specific career field. It acts as a program guide to connect the world of work and life after high school. It serves as a checkpoint of one's progress in determining the requirements needed for entry into a chosen field. The MASTER model serves as a personal plan of action for securing a job in the machine tool and metals-related trades.

Recruitment of qualified workers and the preparation of these workers are of paramount importance within the precision manufacturing industry.

The narratives and charts in this section provide a model along with the "concept documentation" to colleges as they seek to provide guidance to persons who are attempting to identify and to prepare for career opportunities in the machine tool industries. Career Action Plans specifically addresses three groups of individuals.

- high school students seeking career guidance and training;
- displaced workers needing to be re-trained for future employment; and
- individuals who are employed but see a need to prepare themselves for better career opportunities in the future.

High School Students

A career action plan for high school students is at Figure A-1. The following discussion concerning the preparation of an individual career action plan at the high school level is outlined in that chart.

Traditionally, a student's formal career objective begins to materialize during high school. His/her career decision can be influenced by:

- Student's personal master file/profile
- Aptitude
- Interest
- Achievement tests
- Career information provided by high school counselor
- Parental involvement and support
- Design of educational program
- Master schedule maintained by high school counselor

HIGH SCHOOL STUDENTS

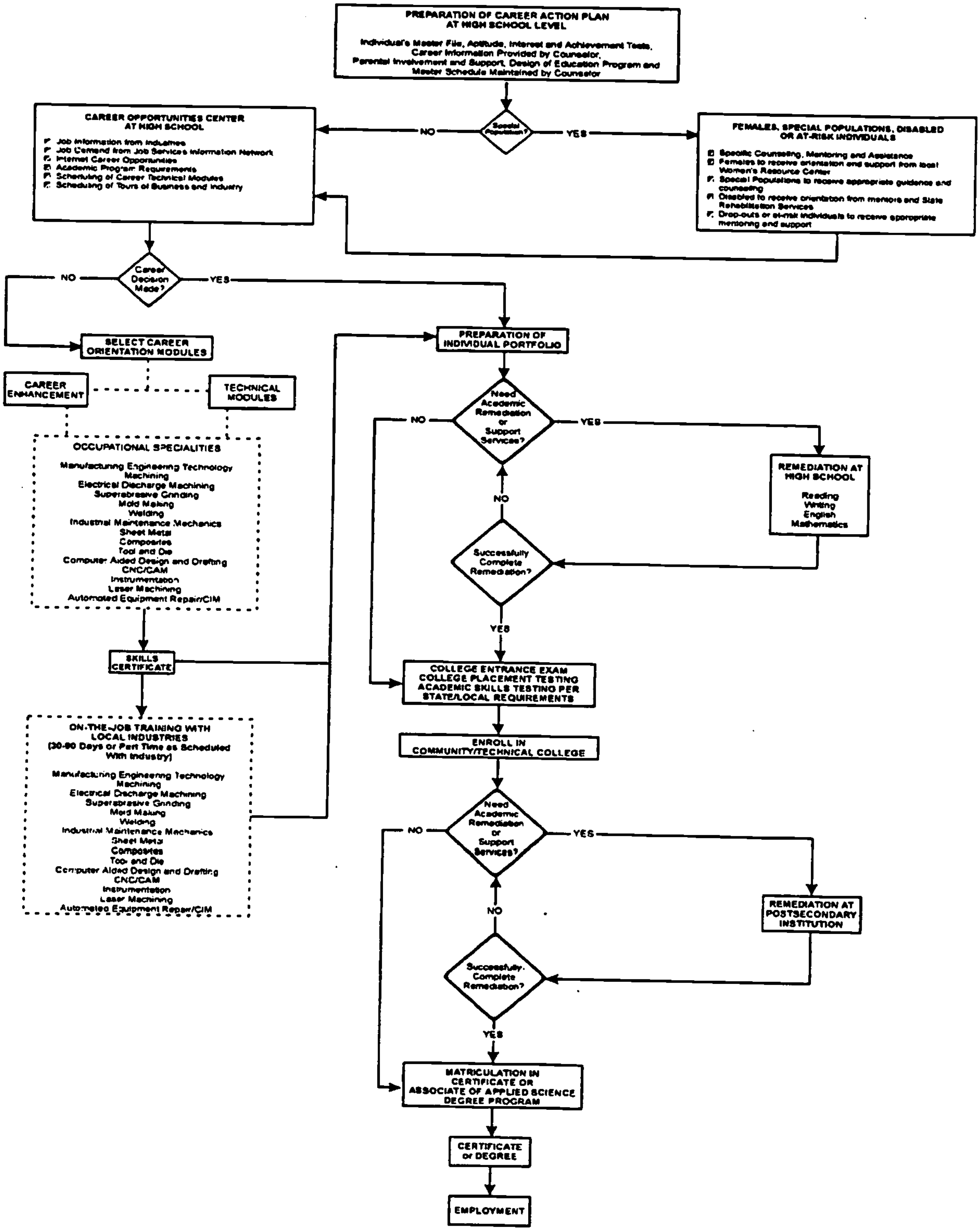

Figure A-1

Student's goals are further solidified by a career opportunities center (or whatever the local forum may be called) offered at high school. Various informational sources also include:

- Career information from industries
- Job demand from Job Services Information Network
- Internet career opportunities
- Academic program requirements
- Scheduling of career technical modules
- Scheduling of tours of business and industry

Of special note is the area of special populations. With precision manufacturing traditionally being a male-dominated field, females, in addition to special populations (economically disadvantaged, educationally disadvantaged, single parent/displaced homemakers, limited English proficiency, disabled and at-risk students) cannot be overlooked. Through various services within the community and institution, support services would address:

- Specific counseling, mentoring and assistance
- Females to receive orientation and support from local women's resource centers
- Special populations to receive appropriate guidance/counseling and financial support to include assistance with food, transportation, shelter, utilities, child care, medicine, etc.:
  - Department of Human Services
  - State Workforce Commission
  - Job Training Partnership Act (tuition, books, etc.)
  - Housing and Urban Development
  - Children Management Services
  - United Way, Goodwill Industries, Salvation Army, etc.
- Disabled to receive orientation from mentors and State Rehabilitation Services
- Drop-outs or at-risk students to receive appropriate mentoring and support from local and state agencies

If a career decision has not been made, the local institution will offer orientation modules (such as the modules which have been produced by the MASTER Program) whereby undecided individuals receive a sampling of the precision manufacturing industry. These orientation modules focus on career enhancement and technical skills. Targeted populations include junior and senior year students. Curricula might include basic shop tools/machine practices and remediation in math, science and personal and group communications.

Moreover, specific remediation modules addressing advanced specialty area courses/modules are included in the MASTER deliverables. These occupational specialities include:

- Advanced CNC and CAM (CNC)
- Automated Equipment Repair Technology (AET)
- Computer-Aided Drafting and Design (CAD)
- Conventional Machining (MAC)
- Industrial Maintenance (IMM)
- Instrumentation (INT)
- Laser Machining (LSR)
- Manufacturing Technology (MFG)
- Mold Making (MLD)
- Tool and Die (TLD)& Electrical Discharge Machining
- Welding (WLD)

Curricula completion would lead to a skills certificate and further student enlightenment as to the opportunities relative to the machine tool industry. As involvement becomes more intense, interested students may enter on-the-job-training with local industries (30-90 days or part time, as scheduled with industry) with further emphasis on the various occupational specialities, as listed above. The end result would lead to consideration of enrollment in college and/or possible entry-level employment. On-the-job training in the form of early work experiences allow the student to begin to specialize after he has had the opportunity to consider the various specialties with the machine tool industry.

With or without an on-the-job training option, the individual's personal portfolio (a history of student performance, documenting ones's progression and achievements in various areas with emphasis upon knowledge, experience and skills) is analyzed to determine the need for academic remediation and/or support service(s). If remediation is necessary, said remediation at the high school level shall address reading, writing, mathematics and English, whereby additional remediation will be contingent upon a student's pass/fail status. Additional remediation may be necessary early on in college based upon personal need or actual state requirements. For example, the State of Texas requires the completion of a testing instrument called the *Texas Academic Skills Program (TASP)*. Prospective college students must pass the test or take remediation courses in weak areas until they pass, or they cannot continue to pursue a college degree.

Typically, secondary schools provide a direct pathway for most students, offering career information and preparation in basic academic skills. If a high school student's career decision has been initially made without the need for external guidance, the individual's personal portfolio is analyzed to determine their need for academic remediation or support service(s). If remediation is necessary, the remediation at the high school level shall address reading, writing, mathematics and English, whereby additional remediation will be contingent upon a student's pass/fail status. Hopefully that remediation is heavy on technical math.

If the high school portfolio does not reflect a need for academic remediation and/or additional support service(s), they would directly enroll in a community/technical college machining certificate/associate degree program.

Unemployed, Out-of-school and Displaced Workers

A career action plan flowchart follows as Figure B-1 for unemployed, out-of-school and displaced workers. The following discussion concerning the preparation of a career action plan is outlined in that chart. This plan would be addressed during their initial visits to the college campus.

Once an individual exits high school, they may be classified as unemployed, out-of-school or displaced. Career decisions, at this point, may be influenced by:

- Individual's personal master file/profile
- Aptitude
- Interest
- Achievement tests
- Career information provided by college counselor
- Design of educational program
- Master schedule maintained by college counselor

Further direction can be attained by investigating a career opportunities center at the local community or technical college. Informational sources include:

- Career information from industries
- Job demand from Job Services Information Network
- Internet career opportunities
- Academic program requirements
- Scheduling of career technical modules
- Scheduling of on-the-job training modules
- Scheduling of tours of business and industry

Females, special populations, disabled and at-risk individuals are of particular interest. With the workforce becoming highly diversified, specific needs of these targeted individuals must be met in order for recruitment of this group to be successful. Support services within the community and institution would provide:

- Specific counseling, mentoring and assistance
- Females to receive orientation and support from local women's resource centers

UNEMPLOYED, OUT-OF-SCHOOL AND DISPLACED WORKERS

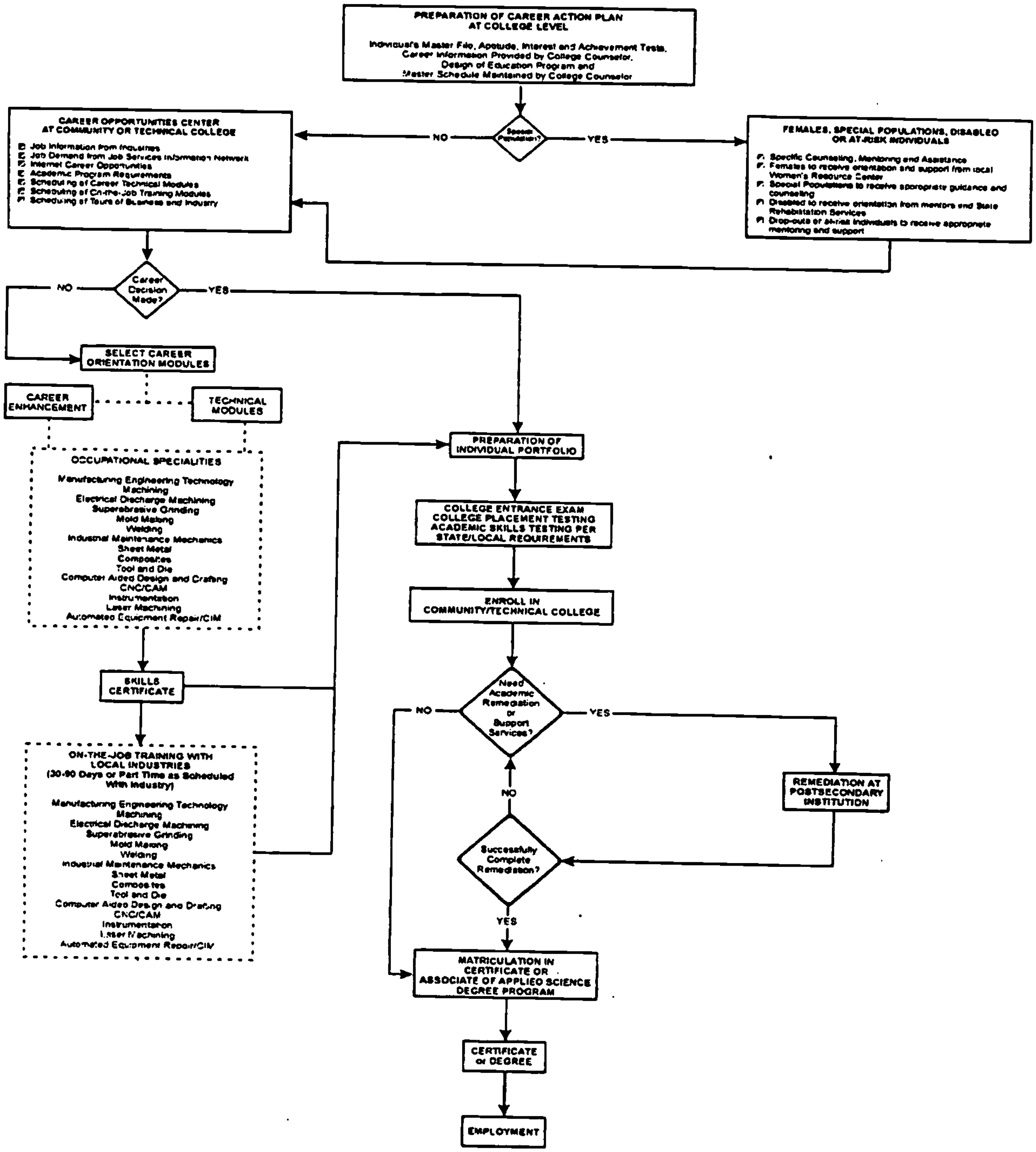

Figure B-1

- Special populations to receive appropriate guidance/counseling and financial support to include assistance with food, transportation, shelter, utilities, child care, medicine, etc.:
  - Department of Human Services
  - State Workforce Commission
  - Job Training Partnership Act (tuition, books, etc.)
  - Housing and Urban Development
  - Children Management Services
  - United Way, Goodwill Industries, Salvation Army, etc.
- Disabled to receive orientation from mentors and State Rehabilitation Services
- Drop-outs or at-risk individuals to receive appropriate mentoring and support

If a career decision has not been made, the local institution will offer orientation modules (included in this volume) whereby undecided individuals receive an orientation of the machine tool industry. These modules should focus on career enhancement and basic technical information. Targeted populations include those unemployed, out-of-school and displaced workers who are needing additional career guidance.

Advanced specialty area courses/modules at the postsecondary level concerning occupational specialties which are included in the MASTER deliverables. These occupational specialities include:

- Advanced CNC and CAM (CNC)
- Automated Equipment Repair Technology (AET)
- Computer-Aided Drafting and Design (CAD)
- Conventional Machining (MAC)
- Industrial Maintenance (IMM)
- Instrumentation (INT)
- Laser Machining (LSR)
- Manufacturing Technology (MFG)
- Mold Making (MLD)
- Tool and Die (TLD)& Electrical Discharge Machining
- Welding (WLD)

Successful completion would lead to a skills certificate and further consideration relative to the opportunities of the machining industry. Moreover, interested persons may enter on-the-job training with local industries (30-90 days or part time, as scheduled with industry) further emphasizing the various occupational specialities, as listed above, which may lead to further specialization and an associate degree.

Currently Employed Workers Upgrading Job Skills

A career action plan flowchart follows as Figure C-1 for currently employed workers upgrading job skills. The following discussion concerning the preparation of a career action plan at the college level is keyed to that illustration.

The technological revolution has necessitated the need for individuals and existing workers to be trained in new frontiers that are required for economic survival and growth. Delivery of new technologically up-to-date machines require the operator to be fully trained to take advantage of the capabilities of that new machine. The speeds, feeds and automated cutting and grinding processes available on a new machine, or a set of devices all operated by one man is extraordinary. The cost savings associated with training the operator to handle the new equipment is tremendous. Educational institutions and industry must aid in producing and supporting a more highly skilled employee.

A currently employed individual may be sponsored by his company for on-site training at the shop/plant, or could attend classes on campus either on his own or with company support. A Remote Site/Industrial Training Model is enclosed in this volume to help technical colleges prepare for collaborations and contracts with industries for credit or non-credit training.

Employers increasingly depend on people who can put knowledge to work. The opportunities for an individual with a good, solid technical base to expand can be located by:

- Career information from industries
- Job demand from Job Services Information Network
- Internet career opportunities
- Review academic program requirements

Careers in precision manufacturing have traditionally been oriented toward the male population. Females, special populations, disabled and at-risk individuals, with the desire to upgrade their job skills, will find support services to encompass:

- Specific counseling, mentoring and assistance
- Females to receive orientation and support from local women's resource centers
- Special populations to receive appropriate guidance/counseling and financial support to include assistance with food, transportation, shelter, utilities, child care, medicine, etc.:
    - Department of Human Services
    - State Workforce Commission
- Job Training Partnership Act (tuition, books, etc.)

CURRENTLY EMPLOYED WORKERS UPGRADING JOB SKILLS

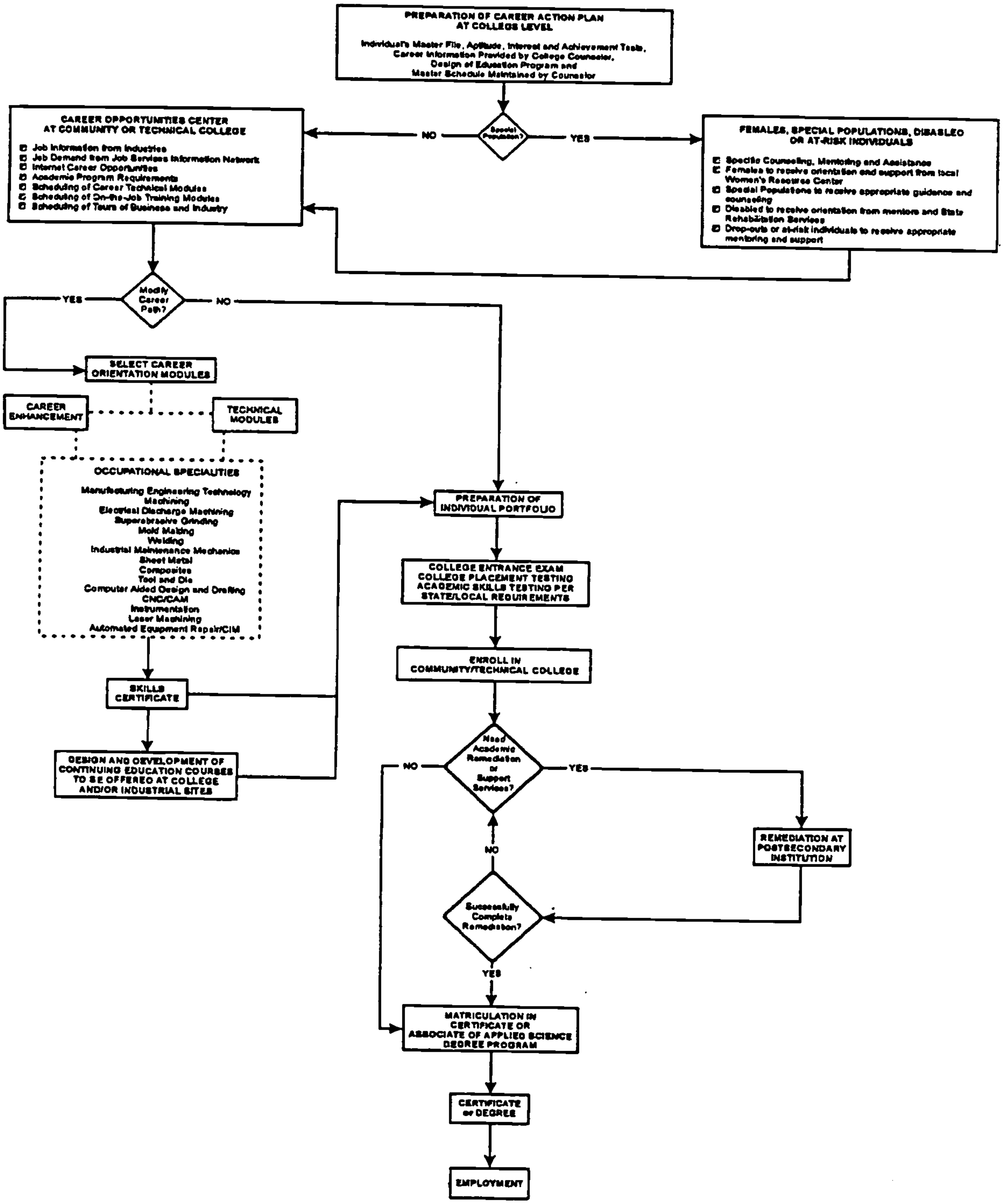

Figure C-1

    - Housing and Urban Development
    - Children Management Services
    - United Way, Goodwill Industries, Salvation Army, etc.
- Disabled to receive orientation from mentors and State Rehabilitation Services
- Drop-outs or at-risk individuals to receive appropriate mentoring and support

Advanced specialty area courses/modules at the postsecondary level concerning occupational specialties are included in the MASTER deliverables. These occupational specialities include:

- Advanced CNC and CAM (CNC)
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- Tool and Die (TLD)& Electrical Discharge Machining
- Welding (WLD)

Individuals desiring additional upgrading may enroll in specific precision manufacturing enhancement courses offered through continuing education classes at the local college and/or industrial site. Interest in this field may lead to entrance into college in a formal industrial technology degree plan and/or possible employment.

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Part One

Part Two

Job Development Center Model

Today, individuals are limited only by their imagination. Everyone wants to succeed, but most still hold to the traditional view that the only path to success is through a 4 year degree. Parents, in particular, believe that this is the best option available for their children. The facts, however, show that skilled technicians actually enter the workforce at a higher rate of pay than the average 4 year college graduate.

Times have changed. The American dream has not changed, but the way to achieve it has. The ladder to success has turned into a speedway for technology. Like a high-powered machine, technology is accelerating at such a fast pace many are left behind. In a world full of ex-bankers, brokers and business majors; skilled educated technicians are competing very well indeed.

Job development for this new world includes preparation for employment and industrial contact. Outside the formal structure of educational institutions, students need the ability to connect with the real world when addressing the issues of career development. Today's job seeker must not only be well trained in a particular career field, he/she must also be well equipped with the polished techniques of knowing how to land the ultimate job.

As the nation recognizes and responds to the need for newer and more effective methods of training and upgrading skills, individuals who acquire those skills will also require assistance in securing employment. A Job Development Center should address job placement services to help reduce the time frame of unemployment or underemployment. While employers are expecting skills, in addition to formal degrees, colleges must expand their services to meet the demands of the work place through continuing education, training centers and contract education with industry. Targeted groups include not only the traditional student; placement services will also need to include those who are returning to be retrained. Moreover, placement centers must offer targeted assistance for a growing group of special populations, such as the disabled, single parents, dislocated workers, whose needs offer new challenges for placement departments. Ideally, a Job Development Centers should serve as a one-stop shop for those needing and seeking comprehensive career educational and job training information.

Job Development Center

Success in a global economy must start in the schools. Students must be prepared to tackle the challenges that technology brings to them. But educators must be willing to keep up with modern technological advances. Staying up-to-date with industry, however, is not the school's only challenge. In today's environment, a technical or community college must go beyond the normal placement business. Job placement is but one aspect of what a college's Job development Center must accomplish for it's students. The student's file should be managed from the point of his initial inquiry to well after his employment for follow on assessment to monitor and adjust curriculum to fit not only current industry requirements, but future trends as well. A Job Development Center really needs to take a "Life Cycle" approach.

Job development is an infinite process. It encompasses life's experiences to include influences that serve as a guide in directing one to a particular career field. One's personality, skills, talents, interests, environment and social life all play a part in job development. It focuses on the culmination of life's experiences when addressing career choices. It is also a fluid process; as society changes, so does an individual's interests, as technology continues to shape the current and future job market.

A Job Development Center serves as a facilitation organization to help students reach their career goals by offering career advisement, support activities and employment assistance and employment follow-up and assessment. The center should basically assist students in planning, preparation and placement (Figure A-1).

Job Development Center

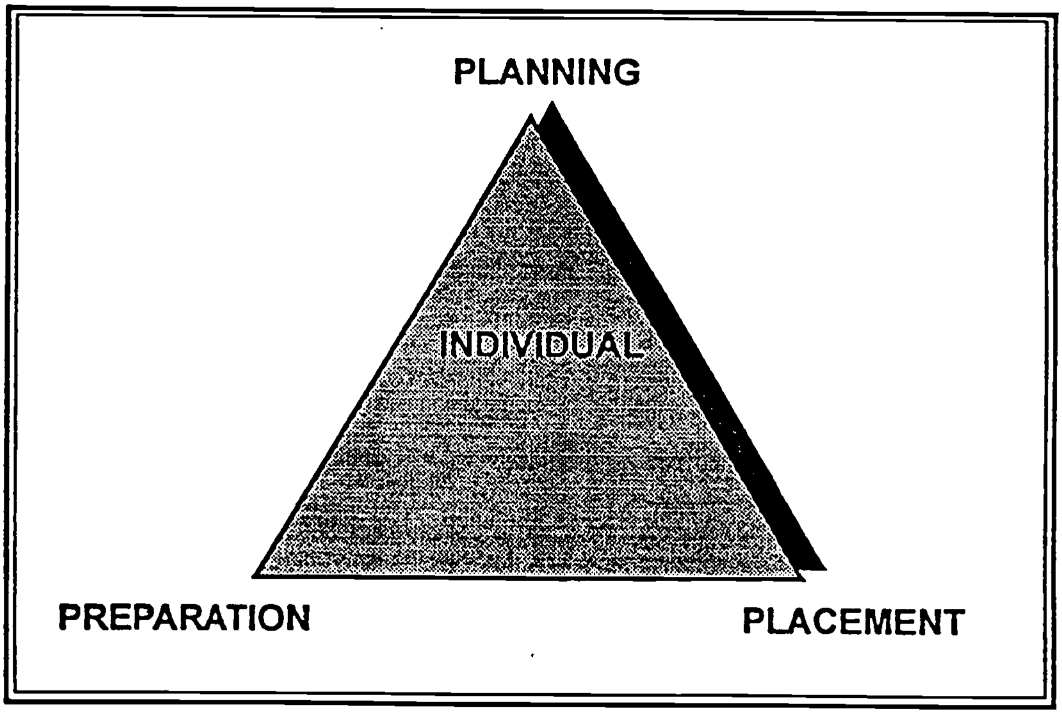

Figure A-1

Planning

Planning involves a process whereby, based upon one's unique personal inventory (skills, interest and aptitude), individuals can make intelligent educational and career choices. Job Development planning should encompass personal, social, educational and career goals.

The planning process is infinite in structure and must undergo periodic review. Job Development Centers should aid students in identifying personal capabilities, values, needs, and the impact they have on career choices. Centers assist in paralleling an individual's makeup with a specific occupational field. It also helps students fine-tune career and lifelong goals based upon an understanding of oneself and the real world, resulting in individualized career plans. Moreover, these influential processes should be a joint effort between counselors, faculty, family, friends, industry representatives and alumni, expanding upon experiences such as formal/informal education, career exploration, job shadowing, and internships or apprenticeships.

Preparation

To effectively prepare clients in meeting their needs, the center should address several basic goals:

- Provide a library of up-to-date career information;
- Aid clients in researching career fields which match their individual interest, aptitude, etc.;
- Provide services such as achievement testing, aptitude testing, career interest inventories, computerized career exploration, etc. to better determine career possibilities;
- Support career-related educational instruction in coordination with faculty; and
- Establish the framework for parents and industry representatives to share in career goals.

Information provided by centers should include:

- Occupational data for civilian and military careers that address training requirements, job duties, placement statistics, job outlook, advancement and labor market information;
- Training data related to universities, community colleges, vocational-technical institutions, apprenticeships and on-the-job training;
- Information to assist in making career choices, such as survey evaluations and tests of individual's interests and aptitudes;
- Local/state/federal test preparation material concerning educational and career choices;
- Career exploration and job seeking information relative to employment applications, resumes, cover letters, interviewing techniques, etc.; and

- Information related to scholarships, financial assistance, admissions assistance.

Placement

One of the primary purposes of a Job Development Center is to focus on employment opportunities for students and graduates. The mission includes not only career assistance while one is attaining his/her educational goals, but also career placement once the individual has completed his/her education.

Job placement services should (1) provide resources and job search strategies that enable students to achieve their goals, (2) serve as a communication channel between instructors, counselors and placement staff, (3) establish and market relationships between industry/business to secure co-op, internship and employment opportunities, (4) coordinate employment prospects for graduates and (5) organize career information and opportunities.

The ability to secure employment is of paramount importance to society. Trends indicate that post secondary institutions are being challenged reference placement accountability. With recruitment and retention becoming major issues concerning institutions, a student's college choice is determined not only by career interest, but also by placement statistics and salary analysis, which are valuable services provided by career centers. Data concerning the types of jobs graduates are securing, numbers of students being placed, whether individuals are employed in related fields of study and average starting salaries all contribute to educational and career decisions. Overall, the functions of job placement services should address pre-employment preparation, job development, career placement and follow-up/follow-through.

Pre-Employment Preparation

Pre-Employment preparation is the process by which one obtains the necessary skills to secure and keep employment in their chosen field. Preparation includes techniques involved in the job search, accurately completing employment applications, customized resumes and polished interviewing tactics. When mastered, these techniques should remain with the individual for a lifetime, as job turnover and competition for specific jobs continue to increase.

The job placement center is in the unique position to offer the skills that are necessary for the transition from school or unemployment to work. The center may offer workshops, seminars and individual sessions for students. Also, integration of resume writing/interviewing techniques may be incorporated within classes, with the cooperation of faculty and placement center staff. Ideally, a credit or non-credit career course may be added to an institution's curriculum.

Pre-employment preparation should address:

- Pre-Employment instruction and counseling:
  - Plan of action for job hunting
  - Obtaining employment information
- Career objectives:
  - Targeting type of job desired, advancement, employment outlook
- Job search process:
  - Sources and location of employment
  - Placement assistance within the college, other organizations and identification of key individuals
  - Employer preference concerning skills, attitudes, etc.
  - Job referrals
- Resume preparation
- Completion of job applications
- Interviewing skills and techniques:
  - Proper dress/grooming
  - Questions asked by the employer
  - Questions asked by the interviewee
- Employability skills:
  - Teamwork orientation
  - Computer literacy
  - Proper workplace readiness skills
  - Good work ethic
  - Positive attitude
  - Punctuality
  - Desire to do the right job
  - Common courtesy
  - Social skills
- Data concerning employment trends and job specifics:
  - Marketing one's credentials with employer needs
  - Listing of employers who have hired prior graduates
  - Institution placement reports concerning employment, entry-level salaries, etc.
- Correspondence to employers:
  - Cover letters
  - Follow-up letters, thank you's after the interview
  - Letters of acceptance/rejection concerning job offers
- Federal/state/local legislation concerning employment

Job Development

Job development is the process of locating and/or creating potential employment prospects for individuals. This includes identifying qualified candidates and matching their skills to business/industry, tapping into new and emerging opportunities within career fields and being on the cutting edge of developing new occupations that were previously non-existent. Although graduate employment cannot be guaranteed by institutions, sufficient potential employers should be developed in each career field. As verification of educational effectiveness remains a primary issue, a joint effort between business/industry and placement centers must exist, as verification of educational effectiveness remains a primary issue. Since college customers include not only the student, but also the hiring entity, job development functions must address the need to locate potential employers for students and to locate qualified persons for the business sector. Job development is a two-way street; job centers must establish an on-going, mutually beneficial relationship with the business sector in order for students to have ample employment options. Community networking and an active advisory council that includes representatives from education, business, industry, trade associations, community leaders and technical instructors contribute to effective job development.

Job development includes determining students' employment needs and building correlated employer files. The types of educational courses offered at the institution serves as the basis of job development, and student employment needs will determine the types of employment opportunities available. An employer list should identify organizations that are possible employers for qualified students. The result would be a potential match of individual skills/needs of students to that of skills/needs of employers. Job analysis involves the assessment of an employer's needs in determining the proper placement of graduates. Both job analysis and job development go hand-in-hand. Effective job analysis results in the creation of jobs that previously did not exist and successfully identifying sources of employers.

Sources of potential employers include:

- Personal referrals/networking
- Former students
- Current students who are working
- Instructors/staff
- Advisory councils
- Chambers of Commerce
- Employment commissions
- Rehabilitation commissions
- Civil services agencies
- Newspaper advertisements
- Telephone directories
- Employer directories
- Community service organizations
- Public libraries

Placement centers usually contact employers by mail/survey, telephone or personal visitation in order to secure various employment opportunities. Serving as the campus liaison between students and employers, the methods used in advertising the college and candidates to potential employers could include:

- Association newsletter articles
- Radio and television advertising
- Newspaper and magazine advertising
- Professional association coverage
- Business staff meeting presentations
- Resume books
- Resume briefs
- Trade show booths
- Student reunions
- Business/industrial on-site visits
- Business career days/targeted job fairs
- In-house campus interviews

Job Placement

Job placement is not a one-person task. The art of preparing an individual for placement requires the services and commitment of instructors, counselors, administrators and support staff to ensure students are properly trained and placed. Traditionally, most institutions rely on one central office to bear the responsibility for finding employment for graduates. However, the nature of the college and the fields of study or technologies offered may allow deviance from the traditional central placement office concept. For example, due to the diversity and intensity of technical curricula, a technical/vocational college may offer placement assistance within each individual technology. As programs require constant revision, due to the nature of technology, a department chair or instructor may be charged with the responsibility of placement. In terms of streamlining, this method may be more effective and specific; industry can negotiate directly with each department, and the end result would be more one-on-one, specialized attention to the needs of both the student and employer. In essence, departments that are responsible for the recruitment, education and placement of students remain more in touch when referencing accountability and effectiveness.

Nevertheless, a coordinated effort between a placement center and a program must exist in order for students to be prepared to enter the job market. The placement service is a support system of pre-employment information, resume preparation, job search and interviewing skills that are necessary for one to find employment with the least amount of expended time and effort.

To assist personnel in job placement, a center should address:

- Supporting and placing individuals in internships, cooperative education programs, community contact programs (community clubs/organizations willing to offer career planning assistance) and part-time, on/off-campus employment programs;
- Maintaining a student placement file referencing his/her skills, goals, personality, salary requirements, geographic preference and work history;
- Administering student pre-employment interviews to review the student's qualifications, occupational objective, type of job desired, resume and interview preparation;
- Maintaining a record-keeping system to effectively match position requirements to student's qualifications;
- Developing a system of job information distribution, unique to the needs of each institution (on-line campus data systems, bulletin boards, job binders, etc.);
- Directing individuals to various job openings (mail outs to graduates, resume/candidate screening, etc.); and
- Administering follow-up activities to students and employers after job referrals.

Follow-Up

Institutional effectiveness and accountability are of paramount importance to any organization. A properly orchestrated follow-up system provides information that can be used in the evaluation of departments and in the documentation of data for future planning. Analysis of survey data can pinpoint individuals who are employed/unemployed and those who may need additional training. Follow-up information can also serve as a baseline in the evaluation of support services, educational departments, existing curricula and the development of new training programs.

Methods of capturing effective follow-up information include:

- Graduate surveys
- Non-completer surveys
- Employer surveys

Graduate Surveys

A graduate survey, either by mail or phone, is an excellent method of obtaining feedback from alumni concerning how effectively an institution prepared them to enter the workforce. Data captured would incorporate employment status, employing company, educational and support service effectiveness and recommendations for improvements. Moreover, placement statistics concerning each department can be compiled to document program performance, in addition to being a useful tool in marketing/recruitment and in meeting local/state/federal governmental standards. Factors such as those employed in a related/non-related field, those who entered the military or continued their education, those who are seeking employment or are unavailable for employment can be documented in a summary report that is unique to the institution and elaborated upon when referencing corresponding detail reports. Moreover, as institutions strive for a higher degree of accountability and improved methods of student tracking, several states have experimented with pilot projects such as aggregate data sharing between state employment commissions and state educational entities in an effort to further document educational/employment outcomes of students.

Nevertheless, frequency and intensity of follow-up surveys will depend upon an institution's own needs, personnel and resources. Initial, 180-day, one-year and long-term follow-ups should yield information such as:

- Former student's correct address and phone number
- Employer's name, address and job title
- Employment in a related/non-related field
- Entry-level salary, promotions, benefits
- How the student found a job
- Mobility patterns
- Opinions concerning the total educational experience
- Opinions on career readiness
- Additional education received
- Identification of possible new openings within an organization

Non-Completer Surveys

Many institutions conduct surveys of all students who do not officially complete a program. With retention being a major concern, these non-completer surveys help document reasons for one's departure from college and aid in identifying problem areas within the campus.

Employer Surveys

The employer survey is an effective instrument to use when organizations wish to document an employer's satisfaction with an individual and the degree of training he/she received while enrolled in college. As a public relations tool, it may also reinforce channels of communication when targeting new employment opportunities within the company. This survey should highlight:

- Quality of work
- Quantity of work
- Educational/technical training
- Personal skills
- Work preparation in relation to those who did not receive formal training
- Hiring source

- Suggestions for improvement in college curricula
- Future job openings, dates for hiring, etc.

As a whole, follow-up information addresses former students' needs and skills, in addition to capturing employer's and ex-student's evaluation of curricula and the institution. The end result is a higher number of better-prepared individuals entering the workforce.

Follow-Through

Follow-through defines a process of effectively utilizing the follow-up survey data in attaining the institution's placement and training missions. It involves thorough review and reporting of survey information to the appropriate departments in order for change to be successfully implemented. Moreover, data shared with administration, faculty, staff and advisory committees assist in the efficient documentation and facilitation for continued improvement.

As institutional effectiveness and accountability become primary issues, the Job Development Center is in the unique position of providing services in support of the total educational experience when focusing on issues such as recruitment, retention, placement, and follow-up.

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Table of Contents

In Support of School-To-Work: A Model for Internship

Listen carefully, and you can hear the clangor of Weyland Smith's hammer shaping the swords of the ancient Teutonic gods, pounding them out of red-hot iron on his massive anvil. Look closely—those young men there, stoking and striking at his command—they are his apprentices, learning their trade directly from the Master Smith of the gods. And they are also someone else, those apprentices; they are the first teachers of the crafts of Weyland Smith to men. Or so say the old Teutonic legends.

Look there, at that volcano; it is Vulcan's forge; and there, Hephæstus' smithy rests on a different slope. All across the world, the foundries and forges of the ancient gods rise up to recall to us their myths and tales. Through the misty veil of Time we see their glowing fires, their scurrying apprentices and confident journeymen, and we hear their commands shouted over the crash of iron against iron.

What do these ancient stories, some millennia old, have to teach us? We in the United States are so far removed from those times, we are so far above that technology, that nothing but entertainment is to be gained from them. There is nothing else there, right? Surely the Twenty-first Century AD has nothing to learn from the Twenty-first Century BC! No, of course not. . . .

What Is Internship?

At its most basic, internship is any on-the-job training that does not meet the United States' legal definition of apprenticeship. For that reason alone, internship is more flexible than true apprenticeship, with both teacher and student freer to pursue goals in formats that are not necessarily standardized. But freedom in education is, like freedom in all other walks of life, a two-edged sword.

In traditional internship programs, the student spends about two-thirds of the day in formal classrooms at a school. The student continues to take the basic courses required for graduation, but complements them with actual work experience for the other one-third of the day. These programs are called by various names, such as "Co-op" and "Distributive Education." In the best such programs, the student's classroom learning and workplace experience integrate to form a solid foundation for the student. Unfortunately, the good programs are rare.

Why Is Internship Important?

We humans are, by and large, rather conservative in our habits, but we will trash something in a heartbeat if it ceases to serve our needs. For thousands of years, internship (as apprenticeship) was the *only* way to teach the trades. Had the system not worked, we would have invented a new system and done away with apprenticehood.

All of us, educators and industrialists alike, know that direct, hands-on training is the single best way to teach technological trades. Formal education, or "book-learning", forms a useful base for trades, but cannot teach the touch and feel of technology. Only putting the students' hands on the machines can teach that. So why did we give up on apprenticeships and internships? Why not retain the system that is educationally superior? The answer is simple: Money.

Internship programs became too expensive to maintain. Industrialists could not afford to take their most experienced craftsmen off their expensive machines just to teach some rookie how to use them. Those machines had to produce goods so that the company could profit, pay for the machine, and pay the master craftsman. Industry in the 1950s and 1960s was too hard pressed with orders for merchandise to continue to educate its own workforce.

The First Solution

The economic crisis of too much business forced American society to move the education of technical workers out of the field and into the colleges, specifically, the two-year junior and technical colleges. In the era of government solutions, the junior college system was, in and of itself, a competent solution to the problem of worker shortages. The community college could take the time, and had the resources, to offer basic instruction in most technical fields.

This program worked well; industry received good entry-level workers, and the people of the community gained sound educations upon which to build solid careers. The community colleges prospered and reflected the prosperity that they generated in their communities.

But today, that old devil, Money, has raised his ugly head again. The community colleges can no longer afford the incredibly expensive machines that industry utilizes. The lack of funds translates to a poorly educated workforce, as the younger generation does not have collegiate access to modern equipment. The students graduate with something less than an adequate understanding of the machines they are supposed to know, which, in turn, forces industry back to the expensive proposition of apprenticeship.

The Second Solution

Modern internship programs, most frequently called "Cooperative Education" at the collegiate level, are designed as a middle road between apprenticeship and scholarship. Theoretically, they offer the best of both worlds.

A student in machining, for example, attends classes part of the time and works part of the time. Sometimes, this a daily division; more often, the student spends a specific amount of time (a quarter, for instance) entirely at the workplace. Either way would be fine, if the system actually worked the way it was designed.

Why Has Modern Internship Failed?

In real estate, the three most important things are "location, location, and location." In internship, the three most important things are "communication, communication, and communication."

Predictably, internship programs have failed because there was far too little communication amongst the participants. In essence, there was no master plan for the students' education. Students had no idea what was actually expected of them; teachers, no way of judging how much their students had learned; and craftsmen, no format for instruction. The industry became a glorified baby-sitter with several highly-paid and distracted nannies watching their charges. Such a situation benefits nobody, including those who are dedicated to learning despite the conditions around them.

This lack of direction and communication leaves everyone wanting. Students are cheated out of a viable, useful education; educators are made to look obsolete or, worse still, incompetent; and industry is robbed of its most important resource: well-trained workers.

Another aspect of the failure of internships today is neither as clearly defined nor as widely recognized. Specifically, recruitment is a serious problem at the secondary level. Counselors and teachers alike point the highest achievers toward four-year colleges and universities. This is as it should be. The poorest performers are directed into remediation and specialty programs devised especially for them. This, too, is as it should be. But what about the vast majority of students *in the middle?*

Unfortunately, there is nothing for the average students. They are expected to somehow find their own ways in the world, to navigate the pitfalls of college acceptance and enrollment alone, and to pay for it all, too. They are, as it were, rudderless ships trying to sail the High Seas without maps.

Lest someone believe that the secondary schools are totally at fault, it must be quickly shown that college recruiters share in the blame as well, especially those at the very technical institutions which are most attractive to average students. Many college recruiters seem to want to speak only to the top ten percent of secondary students. We must face reality—how many prospective doctors, lawyers, or professors are actually going to run a lathe for a living? The thrust of technical college recruitment *must change.*

For too long, the vast body of students who would be interested in pursuing technical careers has been ignored. Machinists, mechanics, and electricians are not generally found amongst the students of Cicero, Aristotle, and Machiavelli. They are found, however, in the vocational programs of secondary schools all across the country; wood shops and automotive and agricultural programs abound with solid, intent students. They *are not* second-class or second-rate; they are the foundation of the American economy! They are the people to whom Thomas Jefferson entrusted his fledgling Republic. Instead of passively waiting for these students to come to technical colleges, the technical colleges must actively seek them out.

So Why Try Again?

The benefits of hands-on, direct training cannot be underestimated nor can they be understated. The only drawback to direct technical training is its cost. While this cost is significant, the lack of a trained workforce and the resultant loss of potential business may be more costly still.

How can MASTER Help?

The MASTER program utterly eliminates the problem of failed communication in internships. This is accomplished by three methods.

Method One, The MASTER Certificate of Competency

Before any other work could be done, the MASTER staff realized that the duties and tasks of the various technicians would have to be codified. Throughout the United States, the MASTER staff at the several partner colleges collected the data necessary to the compilation of duties and tasks list. (See Appendix A.) The resultant list, in matrix form, is the core of the MASTER Certificate of Competency, and is called the Competency Profile.

The second aspect of the Certificate is the certification itself. Each task box has two smaller boxes inside it; these smaller boxes are for the initials of the instructor of that specific task and the level at which the student performs that task. If there are no initials, then the student has not yet been trained in that task.

The third aspect of the Competency Profile is the set of demonstrable standards which are ranked from one to five. These standards are:

1. Cannot perform this skill.
2. Can perform parts of this skill satisfactorily but requires considerable assistance or supervision.
3. Can perform this skill satisfactorily but requires some assistance or supervision.
4. Can perform this skill satisfactorily without assistance or supervision.
5. Can perform this skill without supervision and with initiative and adaptability to problem situations.

The impact of the Certificate on secondary schools and technical colleges could be even greater than its impact on incumbent workers. When (especially) at-risk students enter the ninth grade, school counselors can present the Certificate to them, not as an alternative, but as a hard record of their achievements. The Profile gives the students a clear vision of where they are headed, through both high school and technical school, and of why they need to take certain classes. The certification standards allow the students to see what will be expected of them in the training. It is the belief of the MASTER staff that this combination of clear vision, definite purpose, and candid expectations will aid in the retention of those students who are in the lower portion of the fifty percent of all students who are in the academic middle. Not only that, but the reality of embarking on a career plan with clear rewards and a definite road to reaping those rewards may result in higher retention rates across the board.

Method Two, The MASTER Technical Training Manuals

But the Competency Profile is just a skeleton, and like all skeletons, cannot stand alone. The muscle of the MASTER Program is the Technical Training Module.

Each technical module is a self-contained lesson. There may be prerequisites to take a particular module, but the lesson of each module fully covers one task from the Profile. The module details the prerequisites, needed laboratory materials, reference materials, and the time required for the module. Moreover, the module contains a complete lesson plan, including an introduction, a presentation outline, and a laboratory exercise and self-assessment (with answer key) for the students. (See Appendix B for module MAC-E3.)

As the students progress, they are not locked into a specific school or company, because the MASTER program is universally verifiable. All its standards and lessons are easily accessed by Internet at http://www.machinetool.tstc.edu. Anyone with access to the Internet can download the materials for use by the trainers at that company or school.

This high level of portability permits both the worker and the company to understand, quickly and easily, what further training the worker needs. For the worker, this technical skills silhouette becomes not only a record but also a billboard, usable to both assert and verify work skills.

Method Three, The MASTER Technical Partnership Board

Finally, MASTER presents a new approach to building communicatory bridges and to forming long-term partnerships between education and industry.

The current practice in education is to have technical advisory committees for each technology which the school offers. When schools had seemingly large budgets and the cost of equipment was relatively lower than today, these TACs worked to the betterment of their diverse programs. The institution of the TAC has, however, been left behind in the technical arena because schools can no longer afford contemporary equipment.

MASTER replaces the TAC with the Educational Partnership Board. The composition of the EPB is not only industrialists, but is also educators and, *sine qua non*, a legal advisor. A board might include the local high school principals, their technical instructors, the technical department instructors from the local community college, industrial trainers, and representatives of the industry's management and labor.

This council would determine the comprehension of the Profile and work to ensure that all students who are in the industrial program are given access to achievement. First, all the members agree on the role of the industrial instructors. The industrial role will probably be limited to the teaching of the most advanced skills which require the most expensive tools. The secondary skills and technical college then work out which of them teaches what, based on their instructional capabilities.

Central to the success of this effort is constant, candid communication. That much has always been true, but MASTER adds a new weapon in the war on ignorance: clear standards directly tied to the world of work. All three components of the MASTER Internship Model actually attack the same foe, miscommunication. With MASTER, the students know what they must learn and how well they must learn it; educators have clear standards by which to judge their students' achievements; and industrial trainers have a ready format for instruction.

What Do Schools Gain From MASTER?

In addition to the possible retention benefits, MASTER provides colleges with a powerful recruitment tool. Recruiters can demonstrate to students, not a new program of study for them, but a continuation of their current educations. There is no need, under MASTER's integrated program, for students to endlessly repeat courses which they have already mastered. And the college, rather than being seen as a parking lot beside the road to life, becomes the road itself. Increased retention and enrollment also help fund the schools through increased contact hours.

Everyone likes to see a successful program. As the work of the internship progresses and grows, the industries and their workers will support funding and legislation that are favorable to the schools which operate the programs. They will also be more receptive to giving student tours of industry and to providing the extra boost for the program that only the personal appearance of one of its graduates can give.

Periodically, the Profile will have to be up dated as technologies change. Because of the work of MASTER, this is not the daunting task it once was. Some tasks, like Algebra, may become obsolete, but they are not going to change much. Therefore, the job of identifying and codifying new tasks, or unique tasks, is limited to one or two at a time.

The format for such changes or additions is already provided, so that they can be seamlessly integrated into existing programs. The curriculum never becomes obsolete.

Use of the MASTER Internship Model can also enhance a school's competitive position because the parameters of cost change. Shared costs are lowered costs. With the EPB's blessing, the school is no longer limited by the equipment the school can afford; the industrial partners provide the equipment at their own facilities. Students and collegiate and secondary instructors can learn to operate the latest equipment at the industrial site.

What Does Industry Gain from MASTER?

Aside from an immediate solution to current training problems, MASTER provides industry with several benefits. The greatest asset of any technical industry is a well-trained labor force—men and women who know what they are doing and do it well. MASTER's solution to training is obvious, but there is yet another aspect of training that has significant impact on technical production industries. Both poorly trained workers and new workers are expensive because they are neither as efficient nor as stable as veterans. MASTER may reduce employee turnover, thereby lowering the long-term costs of training as well as the short-term costs.

Lower turnover through improved education also leads to higher employee morale. People who feel good about themselves and secure in their positions are not only personally happier in their day-to-day lives, they are more productive at their jobs, which leads in turn to higher profits for industry. These profits are generated by lowered employment costs, efficient production, and stability—all generated by lowered employee turnover.

The MASTER modules are the result of a survey of over three thousand companies involved in metals-related industries. The Competency Profile is well-suited to quickly finding the essential elements of each job description. And these modules have been proven to work in pilot tests across the United States.

What Does the Student Gain from MASTER?

Once again, many of the benefits are self-evident. A sound technical education is only the most prominent.

The worker's value is increased under the MASTER program because the worker is no longer limited by what the industry has time to teach. The young worker, who may have been laid off when the company's demand for drill press operators decreased, can now easily move to a lathe. By increasing the value of the individual worker, MASTER helps lower the turnover rate generated by the lay-off of single-skill workers.

New workers can, through the Certificate of Competency, readily document their skills. This is a bifurcated benefit; the worker has not only a demonstrable set of employment skills, but an educational resumé without peer. The Certificate is not only proof, it is advertising for the worker. Older, incumbent workers can also benefit from these aspects of the Certificate, showing that they, too, can and have attained new skills.

MASTER is not really a new approach; it is new tool. The approach is as old as technology itself. Stone knives and arrowheads were once made by apprentices, as were horseshoes, steamships, and automobiles. Somewhere, we almost lost contact between the master craftsman and the student. The MASTER Program restores to the master craftsman the noble responsibility of passing the craft to a new generation.

Look closely—see those young people there, running lathes and working in the bellies of gigantic aircraft? They are the children of the ancient master bronze smiths; the latest generation in an unbroken chain connecting us with our most remote ancestors.

Listen carefully; you can still hear the clangor of Weyland Smith's great hammer.

APPENDIX A

To The Employer

This program requires that all students share in the responsibility for their own vocational development. Our objective is to help learners assume responsibility while acquiring the skills needed to enter productive wage-earning employment. Instruction is competency-based, and students are evaluated on how well they can perform specific skills.

The competencies and specific skills were prepared by a group of expert workers from the occupational field. A "5" rating reflects the degree of competence normally associated with a skilled person with two or more years of experience. The student completing this program of instruction is expected to have the majority of ratings at the "4" and "3" levels. Skills without ratings indicate that the student chose not to study the skill or that the occupational area of specialization did not require that skill. Only skills mastered by the student will be rated by the instructor.

Employers are asked to review these skill ratings periodically so that both the employer and the employee will have an ongoing awareness of the employee's development needs.

Employers may find the Record Of Achievement useful in planning for promotions, assignments, and additional training.

____
Program Director

____
Date

To The Instructor

Instructors are requested to authenticate the degree of mastery achieved by the student by writing the number of the level of achievement in the oval in the task box and initialling in the rectangle in the task box every time the student masters a competency. Later, if a student achieves a higher degree of mastery there may be a second, and possibly a third, authentication by the instructor.

Instructors are also requested to indicate below their full name and school address.

Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization

MASTER

Machine Tool Advanced Skills Technology Educational Resources Program

Certificate of Competency

This is to certify that

has satisfactorily completed the
required competencies acknowledged on the reverse side for the program of

CONVENTIONAL MACHINING

and is hereby granted this certificate

This________ day of__________________ 19_____

____________________ Director

____________________ Instructor

CONVENTIONAL MACHINING

Performance Levels

5	Can perform this skill without supervision and with initiative and adaptability to problem situations.
4	Can perform this skill satisfactorily without assistance or supervision.
3	Can perform this skill satisfactorily but requires some assistance and/or supervision.
2	Can perform parts of this skill satisfactorily but requires considerable assistance and/or supervision.
1	Cannot perform this skill.

INSTRUCTOR WILL INITIAL LEVEL ACHIEVED FOR EACH COMPETENCY

Ratings on the chart are based on industrial performance standards. They are confirmed by an instructor (a skilled and experienced person from this occupation) who views and evaluates performance as he would in the role of an employer or supervisor.

A letter of reference attesting to the individual's attendance, punctuality, and work habits, is available from the certifying organization.

DUTIES	TASKS											
PREPARE FOR EMPLOYMENT	DISCOVER LEADERSHIP ELEMENTS	SPEAK TO GROUPS	MAKE DECISIONS	SELECT JOB PROFILES	PREPARE FOR THE WORLD OF WORK							
PRACTICE SAFETY	FOLLOW SAFETY MANUALS AND ALL SAFETY REGULATIONS/ REQUIREMENTS	USE PROTECTIVE EQUIPMENT	FOLLOW SAFE OPERATING PROCEDURES FOR HAND AND MACHINE TOOLS	MAINTAIN A CLEAN AND SAFE WORK ENVIRONMENT	MSDS/CONTROL CHEMICAL HAZARDS	LIFT SAFELY	IDENTIFY/ CONTROL FIRE HAZARDS					
APPLY MATHEMATICAL CONCEPTS	PERFORM BASIC ARITHMETIC FUNCTIONS	CONVERT FRACTIONS/ DECIMALS	CONVERT METRIC/ENGLISH MEASUREMENTS	PERFORM BASIC ALGEBRAIC OPERATIONS	USE PRACTICAL GEOMETRY	UNDERSTAND BASIC TRIGONOMETRY	USE COORDINATE SYSTEMS	CALCULATE SPEEDS AND FEEDS FOR MACHINING	PERFORM CALCULATIONS FOR SINE BAR AND SINE PLATE	CALCULATE FOR DIRECT, SIMPLE, AND ANGULAR INDEXING	PERFORM CALCULATIONS NECESSARY FOR TURNING TAPERS	CALCULATE DEPTH OF CUT FOR ROUND SURFACES
INTERPRET ENGINEERING DRAWINGS AND CONTROL DOCUMENTS	IDENTIFY BASIC LAYOUT OF DRAWINGS	IDENTIFY BASIC TYPES OF DRAWINGS	REVIEW BLUEPRINT NOTES AND DIMENSIONS	LIST THE PURPOSE OF EACH TYPE OF DRAWING	VERIFY DRAWING ELEMENTS	PRACTICE GEOMETRIC DIMENSIONING AND TOLERANCING (GD&T)	ANALYZE BILL OF MATERIALS (BOM)	SKETCH TOOL DIAGRAMS				
RECOGNIZE DIFFERENT MANUFACTURING MATERIALS AND PROCESSES	IDENTIFY MATERIALS WITH DESIRED PROPERTIES	IDENTIFY MATERIALS AND PROCESSES TO PRODUCE A PART	DESCRIBE THE HEAT TREATING PROCESS	TEST METAL SAMPLES FOR HARDNESS	UNDERSTAND WELDING OPERATIONS	EVALUATE ALTERNATIVE PROCESSES	INVESTIGATE BASIC METALLURGY					
MEASURE/ INSPECT	UNDERSTAND METROLOGY TERMS	SELECT MEASUREMENT TOOLS	ELIMINATE MEASUREMENT VARIABLES	MEASURE WITH HAND HELD INSTRUMENTS	MEASURE/ INSPECT USING SURFACE PLATE AND ACCESSORIES	INSPECT USING STATIONARY EQUIPMENT						
PERFORM CONVENTIONAL MACHINING	PREPARE AND PLAN FOR MACHINING OPERATIONS	USE HAND TOOLS	OPERATE POWER SAWS	OPERATE DRILL PRESSES	OPERATE VERTICAL MILLING MACHINES	OPERATE HORIZONTAL MILLING MACHINES	OPERATE METAL CUTTING LATHES	OPERATE GRINDING/ ABRASIVE MACHINES				
PERFORM ADVANCED MACHINING	PREPARE AND PLAN FOR CNC MACHINING OPERATIONS	SELECT AND USE CNC TOOLING SYSTEMS	PROGRAM CNC MACHINES	OPERATE CNC MACHINING CENTERS (MILLS)	OPERATE CNC TURNING CENTERS (LATHES)	PROGRAM CNC MACHINES USING A CAM SYSTEM	DOWNLOAD PROGRAMS VIA NETWORK					
IMPLEMENT QUALITY ASSURANCE PROGRAMS	DESCRIBE THE RELATIONSHIP OF ENGINEERING DRAWINGS TO PLANNING	UNDERSTAND AND USE QUALITY SYSTEMS	USE STANDARDS TO VERIFY REQUIREMENTS									
UTILIZE COMPUTER SYSTEM	RECOGNIZE/USE OPERATING SYSTEM	USE INQUIRY SYSTEMS	INVESTIGATE BASIC CAD SYSTEMS									

APPENDIX B

MACHINIST SERIES

MASTER Technical Module No. MAC-E3

Subject: **Conventional Machining** **Time: 4 Hrs.**

Duty: **Measure/Inspect**
Task: Measure with Hand Held Instruments

Objective(s):

Upon completion of this unit the student will be able to:

a. Measure with steel rules (metric and inch);
b. Measure with micrometers;
c. Measure with comparison measuring instruments (e.g., calipers, telescope gages);
d. Measure with direct measuring instruments (e.g., vernier, dial and digital instruments); and,
e. Measure with fixed gages (go and no-go gages).

Instructional Materials:

MASTER Handout (MAC-E3-HO)
MASTER Laboratory Exercise (MAC-E3-LE1)
MASTER Laboratory Exercise (MAC-E3-LE2)
MASTER Laboratory Aid (MAC-E3-LA)
Steel Rules (metric and fractional) for each student or group of students
0-1" micrometers for each student or group of students
Assortment of outside (larger than 1") micrometers
1 set inside micrometers
1 depth micrometer set
1 ea. - outside spring caliper and inside spring caliper
6" dial calipers for each student or group of students
Random collection of objects for student practice
1 ea. - Digital micrometer and digital vernier caliper
1 ea. - Set of telescoping gages and set of small hole gages
Examples of "go/no-go" gages

References:

Machine Tool Practices, Kibbe, Neely, and Meyer, Wiley Publishing, Latest Edition, "Dimensional Measurement"

NTMA Modules:

MA-I-05	"Steel Rules"
MA-I-09	"Steel Rules and Transfer Tools"
MA-I-13	"Micrometers"
MA-I-17	"Vernier Instruments"

Student Preparation:

Students should have previously completed the following **MASTER** Technical Modules:

MAC-E1	"Understand Metrology Terms"
MAC-E2	"Select Measurement Tools"

Introduction:

Every aspect of our lives, from the clothes we wear to the cars we drive, is greatly influenced by measurement. For the machinist, measurement is especially important since it is the machinist who is responsible for crafting the tools, fixtures, and components which make up or support virtually every part of our lives. Therefore, it is essential for the machinist to be a master in the use of not only the machine tools, but also the instruments which are used to measure the precision components demanded by consumers today. One of the most valuable assets you can possess is the expert use of the machinist measuring tools and a desire to practice quality consciousness in every aspect of your job performance.

Presentation Outline:

I. Discuss the Importance of Learning and Practicing Proper Measurement Techniques
   A. Show the video "Measuring Tools"
   B. Give each student a copy of the handout "Proper Measuring Techniques"

II. Discuss and Demonstrate Proper Measurement Techniques Using the Steel Rule

III. Discuss and Demonstrate the Use of Micrometer Type Measuring Instruments
   A. Outside micrometers
   B. Inside micrometers
   C. Depth micrometers
   D. Practice and demonstration of skills listed above

IV. Discuss and Demonstrate the Use of Transfer Type Measuring Instruments
   A. Spring calipers (inside and outside)
   B. Telescope gages
   C. Small hole gages

D. Practice and demonstration of skills listed above

V. Discuss and Demonstrate the Use of Direct Measuring Instruments
   A. Vernier calipers
   B. Dial calipers
   C. Digital calipers
   D. Practice and demonstration of skills listed above

VI. Discuss the Purpose of Fixed Gages and Demonstrate Their Use
   A. Cylindrical plug and ring gages
   B. Taper plug and ring gages
   C. Snap gages
   D. Thread plug gages
   E. Practice and demonstration of skills listed above

VII. Complete Practical Exercises **(MAC-E3-LE1)** and **(MAC-E3-LE2)** On All the Above Material

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Practical Application:

Students will practice in the lab with each measuring instrument and complete the Laboratory Worksheet **(MAC-E3-LW)** and turn it in to the instructor for evaluation.

Evaluation and/or Verification:

Given: All the measuring instruments listed in the "Instructional Materials" and appropriate sample workpieces to measure;

The student will: Study the material as presented by the instructor, evaluate his/her skills through the Self-Assessment, and demonstrate those skills through the Laboratory Worksheet.

The standards of skill performance are that the student will:

1. Score 90% on the Self-Assessment;
2. Measure with the steel rule to an accuracy of ±1/64 inch;
3. Measure with the micrometer to an accuracy of ±0.001 inch;
4. Measure with the dial and digital caliper to an accuracy of ±0.001 inch; and,
5. Determine whether the holes, tapers, and threads are within acceptable limits by use of the appropriate go/no-go gages.

Summary:

Review the main lesson points. Hold class discussion and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (MAC-E4) dealing with eliminating variables which affect accurate measurement.

MAC-E3-HO
Measure With Hand Held Instruments
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:

a. Measure with steel rules (metric and inch);
b. Measure with micrometers;
c. Measure with comparison measuring instruments (e.g., calipers, telescope gages);
d. Measure with direct measuring instruments (e.g., vernier, dial and digital instruments); and,
e. Measure with fixed gages (go and no-go gages).

Module Outline:

I. Discuss the Importance of Learning and Practicing Proper Measurement Techniques
   A. Show the video "Measuring Tools"
   B. Give each student a copy of the handout "Proper Measuring Techniques"
II. Discuss and Demonstrate Proper Measurement Techniques Using the Steel Rule
III. Discuss and Demonstrate the Use of Micrometer Type Measuring Instruments
   A. Outside micrometers
   B. Inside micrometers
   C. Depth micrometers
   D. Practice and demonstration of skills listed above
IV. Discuss and Demonstrate the Use of Transfer Type Measuring Instruments
   A. Spring calipers (inside and outside)
   B. Telescope gages
   C. Small hole gages
   D. Practice and demonstration of skills listed above
V. Discuss and Demonstrate the Use of Direct Measuring Instruments
   A. Vernier calipers
   B. Dial calipers
   C. Digital calipers
   D. Practice and demonstration of skills listed above
VI. Discuss the Purpose of Fixed Gages and Demonstrate Their Use
   A. Cylindrical plug and ring gages
   B. Taper plug and ring gages
   C. Snap gages
   D. Thread plug gages
   E. Practice and demonstration of skills listed above

VII. Complete Practical Exercise (MAC-E3-LE1) and (MAC-E3-LE2) On All the Above Material

Name:________________ Date:____________________

MAC-E3-LE1
Measure With Hand Held Instruments
Attachment 2: MASTER Laboratory Exercise No. 1

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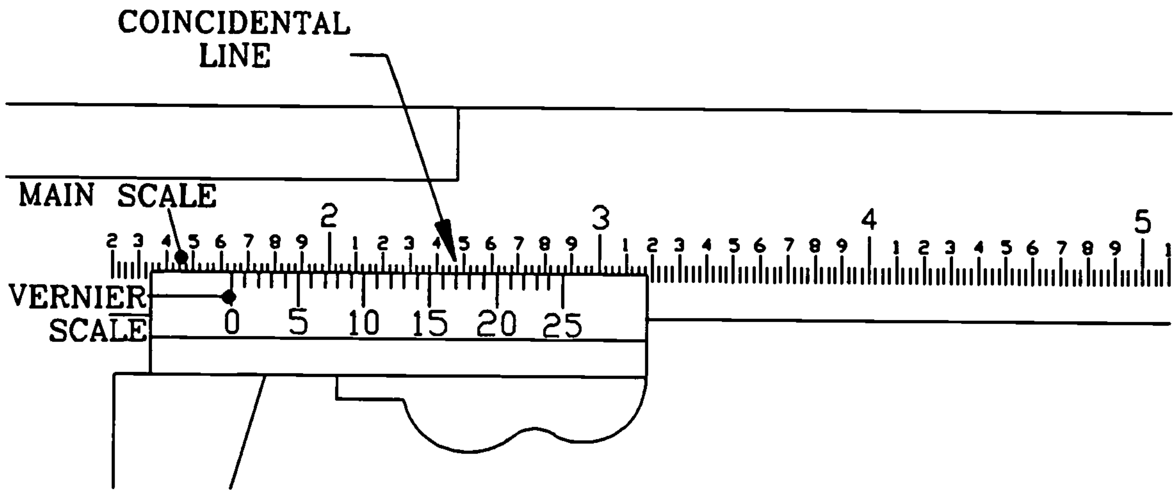
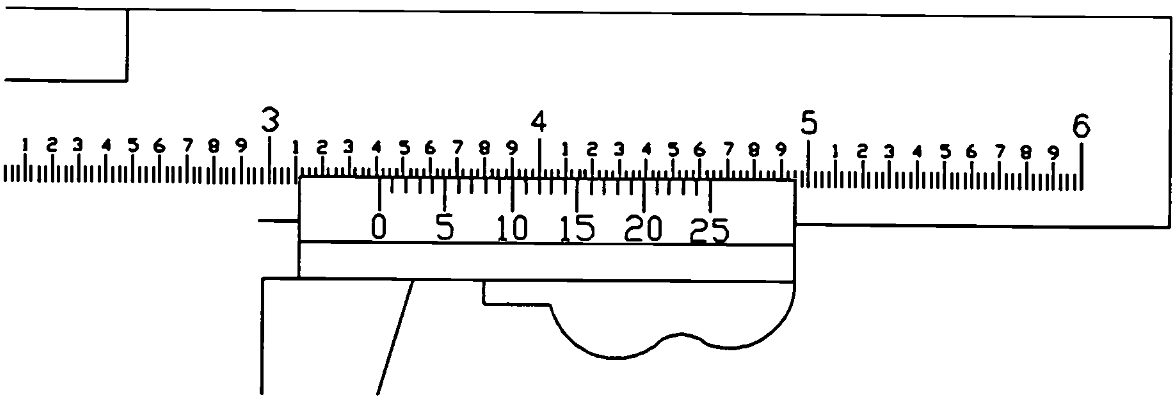
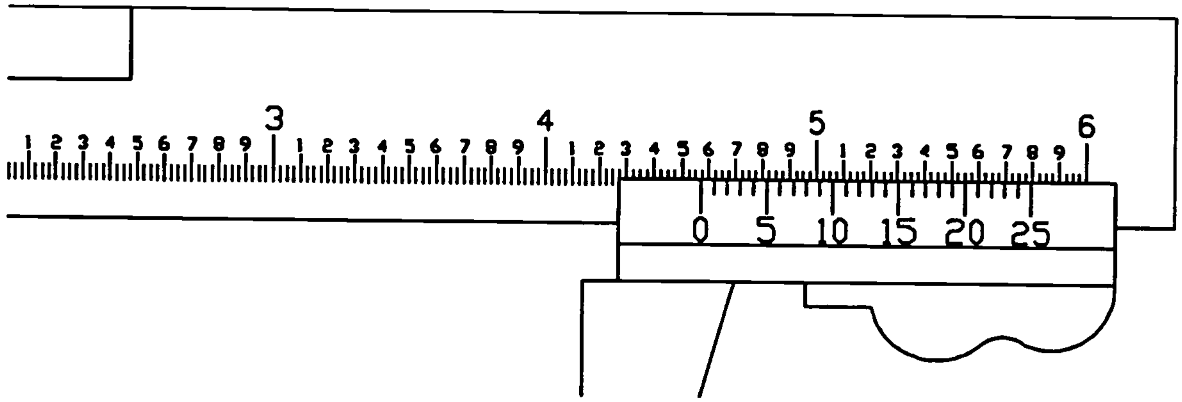
1. What is the reading on the vernier caliper below?
   a. .642
   b. 1.642
   c. 1.645
   d. 1.64



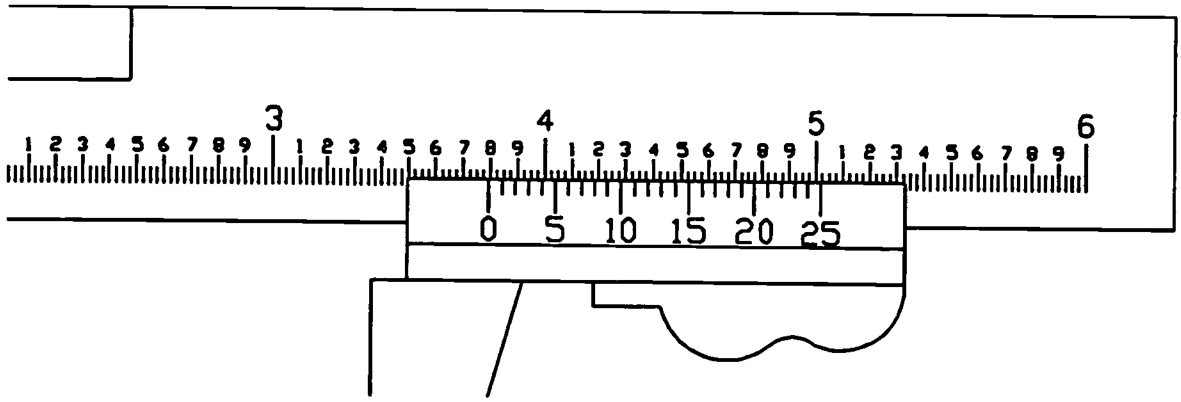
2. What is the reading on the vernier caliper below?
   a. .415
   b. 3.125
   c. 3.405
   d. 3.412



3. What is the reading on the vernier caliper below?
   a. 4.575
   b. 4.250
   c. 4.570
   d. 4.275



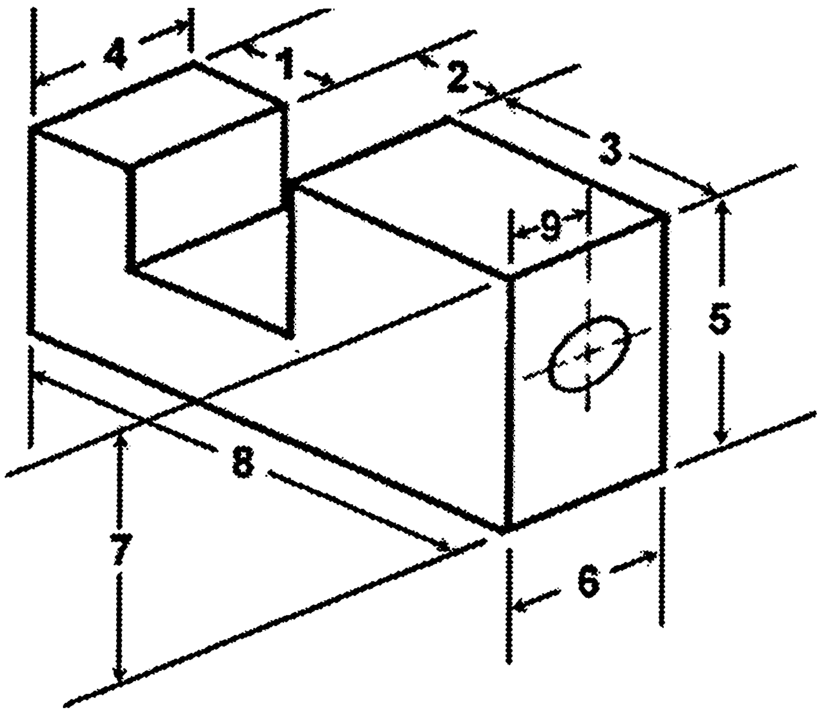
4. What is the reading on this vernier caliper?
   a. 3.785
   b. 3.800
   c. 3.473
   d. 3.793



Name________________________ Date______________

MAC-E3-LE2
Measure With Hand Held Instruments
Attachment 3: MASTER Laboratory Exercise No. 2

Using the measuring instruments provided for you and the measuring specimens, measure for the following dimensions and record your answers in the space provided. Be sure to provide metric and inch answers for each dimension. Turn this sheet in to your instructor for evaluation.



Specimen Number _______

Dimension	metric	inch	Dimension	metric	inch
1.	_____	_____	7.	_____	_____
2.	_____	_____	8.	_____	_____
3.	_____	_____	9.	_____	_____
4.	_____	_____	10.	_____	_____
5.	_____	_____	11.	_____	_____
6.	_____	_____			

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Table of Contents

Part One

Part Two

MASTER Industrial Training Program

It is abundantly clear to those in industry for whom this program is being developed that the key to future success in the competitive worldwide marketplace is the technical skill of its workforce. The issue is further complicated by the aging of the current skilled workforce and the fiercely competitive recruitment of a limited number of new skilled technicians. Indeed, smaller companies of 50 or less employees have become the training ground for larger companies while at the same time being the companies most likely to have future job growth potential.

Technical knowledge and skills, unbiased with the ability to continue in a lifelong learning cycle, are the functional training requirements for the future. The MASTER Project provides a validated and tested industrial training model which addresses the rapidly changing needs of the machine tool and metals-related manufacturing industry. A comprehensive series of technical modules have been developed which are cross-referenced to existing national skill standards projects and the soft skills of communications and problem solving. The intent is to provide any metals or metals-related manufacturing company the tools required to implement a continuing cycle of training, retraining and cross-training workers for today and tomorrow.

The Training Program

- Advanced CNC and CAM
- Automated Equipment Repair
- Computer-Aided Design and Drafting
- Industrial Maintenance Mechanics
- Instrumentation
- Laser Machining
- Conventional Machining
- Manufacturing Technology
- Mold Making
- Tool & Die and Electrical Discharge Machining
- Welding

Each of the Training Program Areas has been carefully developed through a process with multiple industries dependent on a skilled workforce from the respective program area. The skill competencies identified were integrated into a Duties and Tasks matrix which is the basis for developing individual training modules. The matrix was reviewed by each participating industry and then validated by a national survey of 168 metal working companies.

The Product

The completed Training Program covers eleven skill specialty areas and is comprised of over 800 distinct training modules. Each module is designed as a stand-alone training component. They can be utilized as part of a company training program; they can be utilized for individual self-guided training; they can be provided as guidelines for third-party trainees.

Application

Machine Tool Advanced Skills Technology (MAST) and Machine Tool Advanced Skills Technology Educational Resources (MASTER) Programs have been designed to meet the skilled worker's needs of the precision manufacturing industry. The training strategy and materials resulted from the fact that skill shortages continue to severely limit the productivity within the American machine tool industry. This national need necessitates the training of multi-skilled machine technicians capable of installing, integrating, maintaining, diagnosing, repairing, and modifying technologically advanced equipment systems. The survival of existing industries and the successful introducing of new manufacturing enterprises with advanced technologies require the development of innovative training, new curricula and methodologies. The instructional program is applicable to three (3) audiences. These are (1) new employee; (2) retraining, and; (3) cross-training. Research indicates that a typical student in a training course today is an adult in his or her late 20's, taking occasional classes to enter or advance a career. Research further indicates that educational institutions must become more flexible and accessible to achieve the employment, skill, and quality goals of the modern manufacturing workplace.

New Employee

The learning modules are comprehensive and ideal for the new employee. Not only are technical skills developed, the curriculum is made up of five competencies and a foundation of skills and personal qualities that are needed for solid job performance. Successful completion requires development of competencies such as resources, interpersonal, information, systems, and technology. Foundation skills include basic skills such as reading, writing, mathematics, listening, and speaking. Thinking skills are developed in decision making, problem solving, knowing how to learn, and reasoning. Personal qualities are developed such as responsibility, self-esteem, sociability, self-management, and integrity/honesty.

Retraining

The curriculum and modules are based on comprehensive, national research from leading machine tool industries. Consequently, MAST and MASTER are ideal for retraining and updating skills for individuals. Because of the modular approach, these skills may be technical or foundational.

Cross-Training

One common problem identified in today's industry is the lack of ability to cross- train employees. As industry has become agile and flexible, so has the need for employees to be trained in sometimes several jobs. MAST and MASTER allows this cross-training.

Industrial Training Development Process

Figure 1 shows an eleven-step industrial training development process. This process demonstrates how management can identify training needs of employees. This process can be utilized for training new employees, retraining existing employees, or cross-training existing and new employees. The resulting training could be extensive training for some employees or specific modular training for those whose skills are being updated or cross-trained. The materials from MAST and MASTER will allow all to be ongoing simultaneously. Once the training process is implemented, monitoring, evaluating, and adjusting training is an integral part of the process.

An example of the Eleven-Step Industrial Training Development Process (Figure 1) follows:

Step 1: Using the Duties and Tasks Matrix for Machinist (Attachment 1), identify the areas where training is needed.

Step 2: Obtain management endorsement of the training program. All materials in MAST and MASTER are nationally validated.

Step 3: Develop training and implementation plan strategy, i.e., location for training and time schedule.

Step 4: Acquire MASTER training materials selected in Step 1. Attachment 2 is an example of Module MAC-G3 selected from the Machinist Matrix.

Step 5: The MASTER Machinist Module MAC-G3 contains all relevant instructional directions including training objectives, instructional materials, references, presentation outline, practical application (see Student Laboratory Manual MAC-G-3), and evaluation materials.

Step 6: Select a trainer based on the competencies required by the module selected.

Step 7: Pilot test, evaluate, and critique as required in the selected MASTER module(s). A management review should follow Step 7, again seeking management approval and involvement in the training process.

The following steps are ongoing throughout the process:

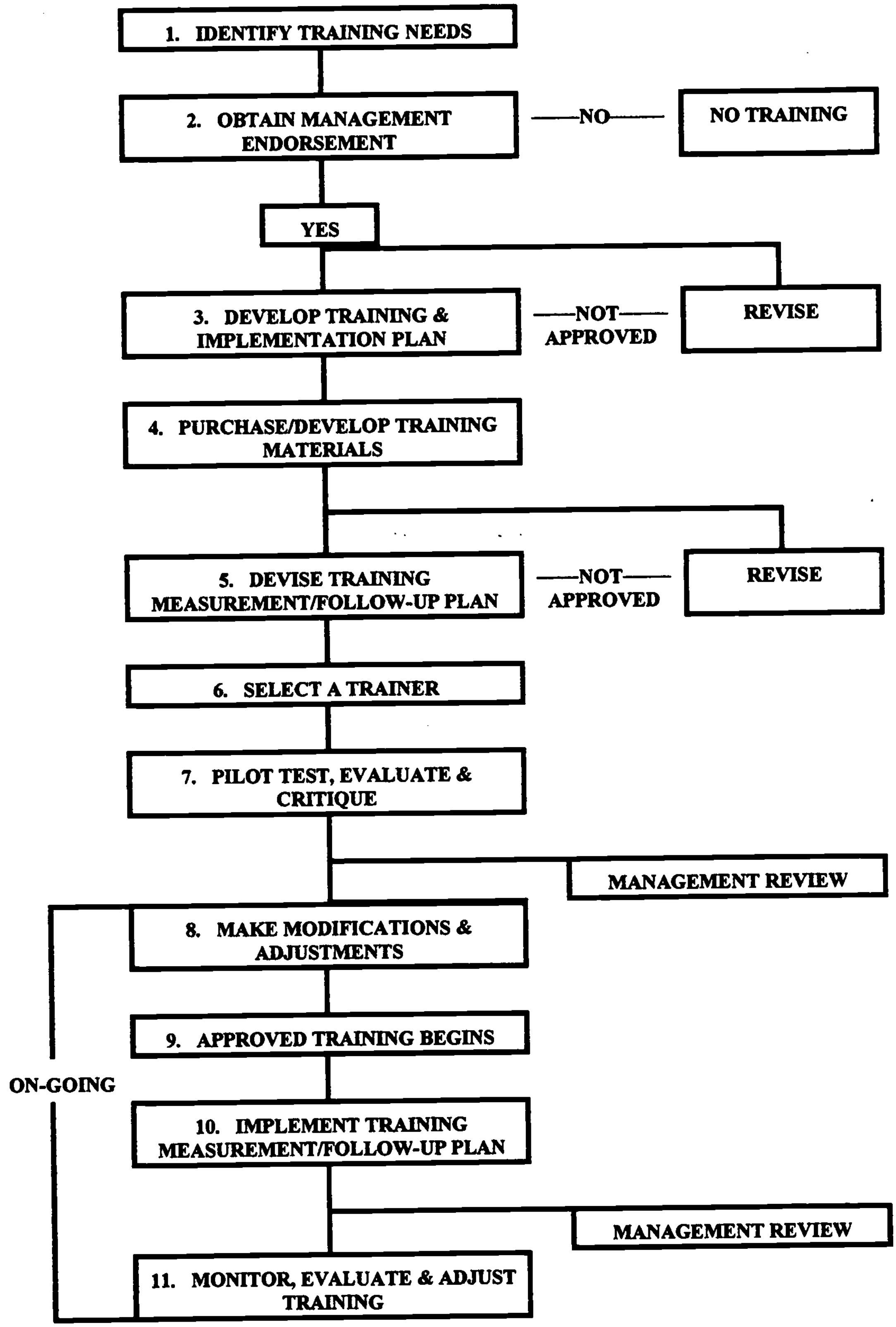
Step 8: Make modifications and adjustments based on previous step (evaluation and critique). For example, it may be found that additional MASTER modules are needed as prerequisites for the desired training.

Step 9: Training is ready to begin.

Step 10: Evaluate the success of the training program based on the ability of course completers to apply new knowledge and skills and student evaluation of the program.

Step 11: Monitor, evaluate and adjust training as needed. Provide certificate and use for human resource development plan. See Attachment 3.

ELEVEN-STEP INDUSTRIAL TRAINING DEVELOPMENT PROCESS



The Matrix – Module

From extensive research involving 2800 participating companies, eleven (11) occupational specialties in the machine tool industry emerged. These are:

- Advanced CNC and CAM
- Automated Equipment Repair
- Computer-Aided Design and Drafting
- Conventional Machining
- Industrial Maintenance
- Instrumentation
- Laser Machining
- Manufacturing Technology
- Mold Making
- Tool & Die and EDM
- Welding

The first and most important task of the MASTER program was the development of a foundation upon which all other works could be built. The MASTER Competency Profile is this foundation. As identified by industry expert workers, the special skills and knowledge, traits and attitudes, and industry trends that would have an impact on worker training, employability, and performance both now and in the future, were identified for each of the above occupations. These results created individual profiles identifying the most common duties and skills required of workers in these occupations. In a matrix format, the combination of these duties and skills result in training modules that yield the specific duties and tasks the worker must accomplish to be successful.

Each training module has been designed to be:

Based on skill standards specified by industry. There must be a direct correlation between what industry needs and what is taught in the classroom and in the laboratory. For many years this type of training has been known as "competency-based training".

Generic in nature. The training materials may then be customized by the trainer, for any given training situation based on the training needs.

Modular in design, to allow trainers to select lessons which are applicable to their training needs.

Comprehensive, include training for advanced and emerging, highly-specialized manufacturing technologies.

Self-contained, including all the components which might be needed by an experienced trainer. These components might include any or all of the following:

- a standardized lesson plan;
- an assessment instrument;
- a listing of commercially available resources (e.g., recommended textbooks, instructor guides, student manuals, and videos); and,

- new training materials, when suitable existing materials are not available (e.g., classroom handouts, transparency masters, and laboratory exercises).

The matrix and modules for each of the eleven (11) occupational areas are shown on the following pages.

Training Delivery

It is the intent of the MASTER Project that the delivery of instruction be flexible to allow industry to work with local educational institutions. An industry may choose to deliver all instruction for an occupational area, e.g., deliver all modules. On the other extreme, all instruction could be outsourced. This instruction could be provided by a local community college/technical institute. Training could be a combination of delivery methods and sites. Industry could provide training they deem necessary (e.g., specific technical training). A community college/technical institute could provide training in modules identified by the industry training department. This training could be on-site or at the college.

AUTOMATED EQUIPMENT REPAIR TECHNICIAN ... operates, programs, maintains, and repairs automated machine tools and automated manufacturing processes.

Duties		Tasks												
A	Apply Science to Solve Industrial Problems	A-1 Apply scientific notation and engineering notation to solve technical problems	A-2 Apply algebraic formulas to solve technical problems	A-3 Use variables in algebraic formulas to predict behavior of industrial systems	A-4 Manipulate variables in algebraic formulas to analyze industrial systems	A-5 Measure, calculate, and convert quantities in English and metric (SI, mks) systems of measurement	A-6 Use mechanical physics to analyze mechanical industrial systems	A-7 Use mechanical physics to analyze mechanical industrial systems	A-8 Use math and mechanical physics to analyze problems found in hydraulic and pneumatic systems	A-9 Use math and thermodynamics to analyze problems found in industrial heat treating systems	A-10 Use math, the physics of electromagnetism and optics to analyze industrial systems	A-11 Use chemical principles and formulas to predict and analyze reactions in chemical industrial processes	A-12 Apply the knowledge of electrochemical effects to analyze chemical industrial processes	A-13 Apply properties of water to analyze industrial water treatment processes
B	Use Drawings to Analyze and Repair Systems	B-1 Use symbols, organization, and engineering values on mechanical drawings	B-2 Use symbols, organization, and engineering values on electrical drawings	B-3 Use symbols, organization, and engineering values on electronic drawings	B-4 Use symbols, organization, and engineering values on fluid power drawings	B-5 Use symbols, organization, and engineering values on digital drawings								
C	Use Calibrated Measuring Instruments to Test/Calibrate Components	C-1 Apply machine tool metrology and measurement instruments to align machine tools	C-2 Apply electrical measurement knowledge and instruments to test/calibrate electrical circuits	C-3 Apply electronic measurement knowledge and instruments to test/calibrate electronic circuits	C-4 Apply fluid power measurement and instruments to test/calibrate hydraulic and pneumatic systems	C-5 Apply digital electronic measurement knowledge and instruments to test/calibrate digital electronic circuits								
D	Resolve System Failures with Critical Thinking, Troubleshooting, Theory, and Metrology	D-1 Apply the troubleshooting process to the resolution of malfunctions found in industrial machine tools and automated equipment												
E	Use Techniques to Isolate Malfunctions of Electrical/Electronic Systems	E-1 Calculate, predict, and measure the response of quantities in DC circuits	E-2 Calculate, predict, and measure the response of quantities in AC circuits	E-3 Calculate, predict, and measure impedance and phase angle in AC circuits	E-4 Calculate, predict, and measure quantities in poly-phase AC circuits	E-5 Properly set up, calibrate, and use meters and oscilloscopes	E-6 Use components such as resistors, inductors, and capacitors; construct circuits and test components	E-7 Use meters/oscilloscopes to measure phase shift or angle in series resistive-capacitive/resistive-inductive AC circuits	E-8 Apply electromagnetism theory to determine operational characteristics of relays, solenoids, transformers, and electrical motors for DC and AC circuits	E-9 Apply principles of operation of electrical motors to identify various types of motors	E-10 Apply semiconductor theory and measurement techniques to determine operational characteristics of diodes transistors, and power control semiconductors	E-11 Apply semiconductor theory and measurement techniques to determine operational characteristics of rectifiers/filtering circuits for single and three phase DC power supplies	E-12 Apply semiconductor theory and measurement techniques to determine operational characteristics of amplifiers and sensors	E-13 Use schematic diagrams, meters, and oscilloscopes to identify, troubleshoot and repair or replace various types of electronic motor control circuits
F	Measure/Isolate Malfunctions of Mechanical/Fluid Power Systems	F-1 Identify and explain the theory and use of major systems that comprise a hydraulic or pneumatic system	F-2 Apply purpose and use of valves in a hydraulic or pneumatic system to troubleshoot components or systems	F-3 Identify, assemble, measure, and apply knowledge of operating characteristics of hydraulic and pneumatic actuators	F-4 Apply hydraulic, pneumatic, and high vacuum systems knowledge to test, troubleshoot, and repair special components/devices	F-5 Identify, assemble, measure, and apply knowledge of operating characteristics of selected, specialized fluid power circuits	F-6 Identify, assemble, measure, and apply knowledge of operating characteristics of electrically operated, specialized fluid power circuits	F-7 Use laws of simple machines and physics to identify and troubleshoot complex machines	F-8 Apply hydraulic, pneumatic, and high vacuum systems knowledge to test, troubleshoot, and repair high purity, high vacuum systems					
G	Apply Computer Science to Computer Controlled Industrial Equipment	G-1 Perform digital operations in digital numbering systems	G-2 Perform Boolean operations in digital equipment	G-3 Solve digital logic circuits and ladder diagrams in electrical and programmable logic control circuits; express a complex logic problem in Boolean and convert it into ladder logic	G-4 Program computers and computer controlled industrial equipment									
H	Correct Malfunctions in PLC Controlled Industrial Equipment	H-1 Perform operations on PLC (programmable logic controller) or PIC (programmable interface controller) systems												
I	Resolve Malfunctions Found in Computer Systems Controlling Manufacturing Processes	I-1 Use equipment manuals, manufacturer's specifications, and data entry/monitoring devices to configure, test and troubleshoot set up of a computer system and solve control problems												
J	Assemble/Disassemble Mechanical Electrical, Electronic, and Computer Systems	J-1 Safely assemble, disassemble, and adjust mechanical systems such as gearing systems, shafts, couplings, pulleys, belts	J-2 Safely assemble, disassemble, and adjust subsystems or components of fluid power systems	J-3 Safely assemble, disassemble, or adjust electrical systems or components	J-4 Safely assemble, disassemble, or adjust electronic systems or components	J-5 Safely assemble or disassemble digital systems or components such as PLCs, CNCs, or computers								

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COMPUTER-AIDED DRAFTING AND DESIGN TECHNICIAN .... plans, lays out, and prepares engineering drawings, parts lists, diagrams, and related documents for layouts, sketches, and notes using manual or computer-aided techniques following current industry and company standards.

Duties		Tasks												
A	Apply Mathematical Concepts	A-1 Perform basic arithmetic operations	A-2 Compute unit conversions	A-3 Perform basic trigonometric operations	A-4 Use the Cartesian coordinate system	A-5 Use the polar coordinate system								
B	Demonstrate Fundamental Drafting Skills	B-1 Use drawing media and related drafting materials	B-2 Use measuring scales	B-3 Identify drafting line styles and weights	B-4 Prepare title blocks and other drafting formats	B-5 Create technical sketches								
C	Plan and Organize Activities	C-1 Determine scope of drafting assignment	C-2 Select appropriate drafting techniques for drawings	C-3 Maintain supporting documents										
D	Prepare Mechanical Production Drawings	D-1 Under-stand and apply mechanical drawing methods	D-2 Create detail drawings	D-3 Create assembly drawings	D-4 Perform technical lettering	D-5 Create bill of materials/ parts list	D-6 Apply dimensions and notes	D-7 Apply dimensional limits and tolerances	D-8 Apply current drafting standards to drawings	D-9 Perform drawing revisions	D-10 Use commercial and vendor data			
E	Assist Engineering Personnel	E-1 Under-stand basic design procedures	E-2 Utilize fasteners for mechanical applications	E-3 Utilize power transmission elements for mechanical applications	E-4 Utilize bearings for mechanical applications	E-5 Under-stand basic manufacturing methods	E-6 Utilize brakes and clutches for mechanical applications	E-7 Design shafts for use in mechanical applications						
F	Use Computer-Aided Drafting System	F-1 Start and exit a software program	F-2 Demon-strate proper file manage-ment tech-niques	F-3 Use directory structure	F-4 Open, save, and exit a drawing file	F-5 Utilize drawing setup procedures	F-6 Use geometric objects (e.g., lines, splices, circles, etc.)	F-7 Use text for drawing annotation	F-8 Use view-ing/display commands	F-9 Control object properties	F-10 Under-stand procedure to print/plot a drawing	F-11 Use standard layering techniques	F-12 Create mechanical CAD drawings	F-13 Create 3D mechanical models
		F-14 Use drawing feature attributes	F-15 Obtain 3D model property data	F-16 Use CAD dimensioning features	F-17 Perform CAD customization procedures									

CNC MACHINIST .... programs, edits, sets up, and operates CNC lathes, mills and grinders to perform machining operations necessary to produce workpieces to referenced engineering standards.

Duties	Tasks												
A Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 MSDS/ control chemical hazards								
B Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems					
C Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G Perform Advanced Machining	G-1 Understand CNC basics	G-2 Program CNC machines	G-3 Operate CNC machining centers (mills)	G-4 Operate CNC turning centers (lathes)									
H Use Verification and Communication Systems	H-1 Use personal computer	H-2 Use various operating systems	H-3 Use computer communications systems	H-4 Use verification systems	H-5 Use the Internet								
I Program Using CAM System	I-1 Understand CAD/ CAM programs	I-2 Manipulate CAD functions	I-3 Process simple tool-path data	I-4 Create advanced surface models	I-5 Process complex tool-path functions								

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INDUSTRIAL MAINTENANCE MECHANIC....uses mechanical, pneumatic, hydraulic, and electrical skills to maintain, repair, and install equipment and machinery used in industry.

Duties	Tasks												
A Practice Safety	A-1 Use protective equipment	A-2 Accident prevention	A-3 Working aloft	A-4 Fire safety	A-5 Lifting safety	A-6 Lockout/tagout							
B Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/decimals	B-3 Convert Metric/English measurements	B-4 Perform basic algebraic operations	B-5 Perform basic trigonometric functions	B-6 Perform basic geometric calculations							
C Interpret Engineering Drawings and Control Documents	C-1 Identify basic types of drawings	C-2 Identify basic layout of drawings	C-3 Review blueprint notes and dimensions										
D Use Measuring Tools	D-1 Use non-precision measuring tools	D-2 Use precision measuring tools											
E Use Hand Tools	E-1 Identify and use maintenance technician's hand tools	E-2 Identify and use hand held power tools											
F Operate Machine Tools	F-1 Use and care of milling machines	F-2 Use and care of horizontal and vertical band saws	F-3 Use and care of pedestal grinder	F-4 Use and care of surface grinder	F-5 Operate lathes	F-6 Use and care of drill press							
G Perform Welding Operations	G-1 Weld with shielded metal arc welding (SMAW) process	G-2 Weld/cut with oxyacetylene	G-3 Perform gas soldering										
H Maintain/Troubleshoot Equipment and Systems	H-1 Maintain air conditioning systems	H-2 Maintain pneumatic control circuits	H-3 Troubleshoot centrifugal pumps	H-4 Troubleshoot positive displacement pumps	H-5 Maintain gate, globe, ball, plug, and butterfly valves	H-6 Maintain check valves and relief valves	H-7 Troubleshoot and repair blowers	H-8 Troubleshoot, maintain, and repair hydraulic systems	H-9 Troubleshoot, maintain, and repair pneumatic systems				
I Repair Power Transmission Systems	I-1 Maintain and troubleshoot belt drive systems	I-2 Maintain and troubleshoot gear power transmission drives	I-3 Maintain and troubleshoot chain power transmission drives	I-4 Maintain and troubleshoot clutches									
J Fabricate/Install Sheet Metal Parts	J-1 Layout sheet metal parts	J-2 Form and/or bend sheet metal parts	J-3 Fasten sheet metal parts together										

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INDUSTRIAL MAINTENANCE MECHANIC....uses mechanical, pneumatic, hydraulic, and electrical skills to maintain, repair, and install equipment and machinery used in industry.

Duties		Tasks												
K	Piping Operations	K-1 Perform basic pipefitting calculations	K-2 Cut, thread, and ream pipe	K-3 Pipe assembly	K-4 Install and adjust pipe support	K-5 Tubing	K-6 Fittings	K-7 Plastic pipe						
L	Basic Rigging	L-1 Rigging fundamentals	L-2 Demonstrate basic rigging skills											
M	Bearing Maintenance	M-1 Plain bearings	M-2 Rolling element bearings											
N	Use Computers	N-1 Perform basic word processing	N-2 Perform basic spreadsheet operations											
O	Align Shafts	O-1 Principles of alignment	O-2 Methods of alignment											
P	Install/Align Machines	P-1 Install electrical connections	P-2 Setting and leveling	P-3 Grouting	P-4 Special mountings									
Q	Maintain Electrical Devices	Q-1 Use electrical test equipment	Q-2 Apply basic terms to electrical circuits	Q-3 Analyze series, parallel, and complex AC/DC circuits	Q-4 Check AC and DC motors	Q-5 Troubleshoot electrical devices								
R	Basic Mechanical Concepts	R-1 Force	R-2 Work	R-3 Mechanical motion and rate	R-4 Simple machines	R-5 Power								
S	Fasteners and Preloading	S-1 Fasteners and nomenclature	S-2 Application for various fasteners	S-3 Techniques for removing damaged fasteners	S-4 Cleaning and restoring threaded fasteners	S-5 Torque/preload theory	S-6 Effects of lubricating threads prior to torquing	S-7 Demonstrate appropriate torquing technique						

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INSTRUMENTATION AND CONTROL TECHNICIAN ... troubleshoots, repairs, calibrates, specifies, and commissions as required all instrumentation and control components relating to plant operations, including dynamic evaluation, testing, controller tuning, and total system performance evaluations.

Duties	Tasks												
A Practice Safety	A-1 Use protective equipment	A-2 Accident prevention	A-3 Working aloft	A-4 Fire safety	A-5 Lifting safety	A-6 Lockout/ tagout	A-7 Use electrical equipment						
B Maintain Control Systems	B-1 Proper storage of circuit boards	B-2 Collect and record data according to company requirements	B-3 Test and calibrate transducers according to specs	B-4 Perform preventive maintenance procedures for control devices	B-5 Test and/ or replace printed circuit boards	B-6 Function check individual elements within loop	B-7 Trouble-shoot different types of system modules	B-8 Test different types of systems modules	B-9 Configure software	B-10 Repair different types of system modules	B-11 Install control system check	B-12 Simu-late control system check	B-13 Loop check control system
	B-14 Perform on-line testing												
C Maintain Field Instrumentation Devices	C-1 Test and calibrate pressure, level, flow, and temperature switches	C-2 Trouble-shoot and repair pressure, level, flow, and temperature switches	C-3 Adjust dampers and positioners	C-4 Trouble-shoot control drive (damper)	C-5 Test and calibrate indicators and gauges	C-6 Trouble-shoot and repair indicators	C-7 Test and calibrate transmitters	C-8 Test and calibrate recorders	C-9 Trouble-shoot and repair recorders	C-10 Trouble-shoot linear variable differential transformers	C-11 Trouble-shoot and repair transmitters	C-12 Test different field sensing elements, flow, temperature, pressure, and level	C-13 Install/ replace field sensing elements
	C-14 Cali-brate trans-mitters	C-15 Tune controllers: pneumatic and electronic	C-16 Trouble-shoot and repair plant computing systems relating to process controls	C-17 Trouble-shoot and repair solenoid valves	C-18 Perform preventive maintenance procedures for field devices	C-19 Test and replace thermocouples	C-20 Check and test vibration sensing elements	C-21 Inspect and troubleshoot power supplies and converters	C-22 Test and calibrate control valve actuators	C-23 Trouble-shoot and repair control valves and positioners	C-24 Test and calibrate controllers	C-25 Trouble-shoot and repair local controllers	C-26 Trouble-shoot and repair electronic computing relays
	C-27 Test and calibrate gas analyzers	C-28 Test and calibrate air analyzers	C-29 Test and calibrate water analyzers	C-30 Trouble-shoot servo valves	C-31 Calibrate servo valves	C-32 Test and clean video display unit	C-33 Check and adjust video display unit	C-34 Design, specify and configure smart field devices, i.e., transmitters and valves	C-35 Operate control systems including single element, cascade, ratio, and feedforeward	C-36 Trouble-shoot and repair analyzers			
D Organize Work Routines	D-1 Organize documents and drawings required on the job	D-2 Deter-mine proper tools/equip-ment/materi-als to perform the job	D-3 Coordi-nate work activities with other crafts or units	D-4 Coordinate preventive maintenance schedule with planning group	D-5 Verify equipment isolation prior to performance of work for safety reasons	D-6 Report abnormal equipment problems to supervisor	D-7 Write new calibration procedures	D-8 Follow specifications and procedures	D-9 Perform algebraic operations	D-10 Perform basic trigonometric functions	D-11 Perform basic calculus operations		
E Collect and File Data	E-1 Record test/calibration data	E-2 Record preventative maintenance data	E-3 Record equipment disconnect data	E-4 Evaluate collected data	E-5 Review/ revise procedures	E-6 Write reports required by company	E-7 Specify equipment for control systems	E-8 Prepare and update specifications	E-9 Write work orders				
F Participate in Continuing Education Activities	F-1 Read/ interpret diagrams and drawings	F-2 Sketch diagrams	F-3 Study technical equipment information	F-4 Application of ISA/JIC standards	F-5 Under-stand proper use of test equipment and tools	F-6 Learn to write technical reports	F-7 Acquire safe practices for handling hydraulic and special tools	F-8 Utilize technical manuals	F-9 Under-stand personal computers	F-10 Attend on-going safety training courses	F-11 Partici-pate in plant related training	F-12 Attend PLC training	F-13 Attend DCS training
G Maintain and Control Inventory	G-1 Learn to review and forecast spare parts inventory	G-2 Prepare parts request	G-3 Verify parts received	G-4 Research/ verify substitute specifications									
H Troubleshoot, Install, Maintain, & Operate Motor Control Systems	H-1 Trouble-shoot, install, maintain, and operate motor starters	H-2 Trouble-shoot, install, maintain, and operate relays	H-3 Trouble-shoot, install, maintain, and operate pushbuttons	H-4 Trouble-shoot, install, maintain, and operate switches	H-5 Trouble-shoot, install, maintain, and operate DCS networks	H-6 Prepare and update ladder and/or logic diagrams	H-7 Program PLCs	H-8 Trouble-shoot, install, maintain and operate PLCs					

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Laser Machinist .... apply the principles of electronics, lasers, optics, materials, engineering documentation, CAD/CAM, and systems integration to manufacture products following current industry and company standards.

Duties		Tasks												
A	Practice Laser Safety	A-1 Discuss laser safety standards	A-2 Discuss basic laser principles	A-3 Discuss laser hazards	A-4 Discuss control measures									
B	Apply Mathematical Concepts	B-1 Perform basic mathematical functions	B-2 Perform algebraic functions	B-3 Study exponents and right triangle geometry	B-4 Study elements of plane and solid geometry	B-5 Perform data evaluation and statistical analysis	B-6 Perform proportioning and interpolation	B-7 Perform basic trigonometric calculations	B-8 Investigate vectors and vector systems	B-9 Investigate the Cartesian Coordiante System				
C	Perform Measurement and Inspection	C-1 Study basics of metrology	C-2 Select instruments used for measurement	C-3 Study datums and the three plane concept	C-4 Select gauging tools	C-5 Use CMM for location of features	C-6 Perform measurements for orientation tolerances	C-7 Perform measurment by optical comparison	C-8 Perform measurements for circularity, concentricity, runout, and straightness tolerances	C-9 Investigate advanced metrology topics				
D	Troubleshoot Industrial Electronics and Control	D-1 Perform DC voltage, current, and power measurements	D-2 Perform AC voltage, current, and power measurements	D-3 Investigate digital logic systems	D-4 Investigate diode applications	D-5 Investigate transistors and thyristors	D-6 Investigate operational amplifiers	D-7 Investigate power supply circuits						
E	Apply Concepts of Modern Optics	E-1 Study reflection and refraction at plane surfaces	E-2 Perform imaging with a single lens	E-3 Perform imaging with multiple lenses	E-4 Study F-stops and apertures	E-5 Use laser beam-expanding collimators	E-6 Study interference	E-7 Study diffraction	E-8 Study polarization	E-9 Investigate radiometry and photometry				
F	Perform CNC Machining	F-1 Apply machine specific nomenclature and terminology	F-2 Investigate the Cartesian coordinate system as applied to a CNC mill or laser	F-3 Apply CNC programming language	F-4 Perform start up, tool changing, and ending of programs	F-5 Perform positioning and basic drilling	F-6 Create a sub-program	F-7 Perform contouring	F-8 Apply tool radius compensation	F-9 Perform program preparation	F-10 Apply special laser coding parameters			
G	Investigate Industrial Laser Systems	G-1 Review characteristics of light	G-2 Investigate emission and absorption of light	G-3 Discuss optical cavities and laser modes	G-4 Discuss temporal characteristics of lasers	G-5 Investigate spatial characteristics of lasers	G-6 Discuss laser classifications and characteristics							
H	Perform Computer-Aided Drafting (CAD)	H-1 Discuss and understand PC basics	H-2 Discuss CAD basics and file management	H-3 Use drawing settings	H-4 Perform basic editing commands	H-5 Create drawings with accuracy	H-6 Organize drawing information	H-7 Control the display of drawings	H-8 Use intermediate drawing commands	H-9 Perform intermediate editing commands	H-10 Create multi view drawings	H-11 Create sectioned drawings	H-12 Investigate basic dimensioning	H-13 Perform advanced dimensioning
		H-14 Use and manipulate blocks	H-15 Use blocks to automate the drawing process											
I	Perform Laser Materials Processing	I-1 Review laser safety standards	I-2 Discuss lasers used for materials processing	I-3 Discuss laser optics and beam characteristics	I-4 Investigate absorption of laser energy	I-5 Use lasers for welding and surface treatment	I-6 Use lasers for material removal							
J	Perform Computer-Aided Manufacturing (CAM)	J-1 Discuss and understand the basics of a PC based CAM system	J-2 Discuss basic CAM operations	J-3 Set up cutting tools	J-4 Create simple part profiles	J-5 Create and edit complex part profiles	J-6 Perform roughing, drilling, and counterboring	J-7 Advanced editing of part profiles	J-8 Edit tool paths	J-9 Use construction layers in SmartCAM	J-10 Perform user commands and machine events	J-11 Create families of parts	J-12 Perform CAD/CAM integration	J-13 Perform code generation

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MACHINIST.... plan, layout, set up, and operate hand and machine tools to perform machining operations necessary to produce a workpiece to referenced engineering standards.

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 Lift safely	A-6 MSDS/ Control chemical hazards							
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems	B-9 Perform calculations for sine bar and sine plate	B-10 Calculate for direct, simple, and angular indexing	B-11 Perform calculations necessary for turning tapers	B-12 Calculate depth of cut for round surfaces	
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice geometric dimensioning and tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations								
E	Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Prepare and plan for CNC machining operations	G-2 Select and use CNC tooling systems	G-3 Program CNC machines	G-4 Operate CNC machining centers (mills)	G-5 Operate CNC turning centers (lathes)	G-6 Program CNC machines using a CAM system	G-7 Download programs via network						

MAC PM6
07/08/97

MANUFACTURING TECHNICIAN .... recommends and implements solutions for specific manufacturing applications.

	Duties	Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 Lift safely	A-6 Control fire hazards	A-7 MSDS/ Control chemical hazards						
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems	B-9 Perform calculations for sine bar and sine plate	B-10 Calculate for direct, simple, and angular indexing	B-11 Perform calculations necessary for turning tapers	B-12 Calculate depth of cut for round surfaces	B-13 Use all functions on a scientific calculator
		B-14 Solve static systems for resultant force	B-15 Determine strength of materials for various applications											
C	Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D	Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations	D-6 Evaluate plastics, composites and other manufacturing processes							
E	Measure/Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F	Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G	Perform Advanced Machining	G-1 Prepare and plan for CNC machining operations	G-2 Select and use CNC tooling systems	G-3 Program CNC machines	G-4 Operate CNC machining centers (mills)	G-5 Operate CNC turning centers (lathes)	G-6 Program CNC machines using a CAM system	G-7 Download programs via network						
H	Program Using CAM System	H-1 Understand CAD/ CAM programs	H-2 Manipulate CAD functions	H-3 Process simple toolpath data	H-4 Create advanced surface models	H-5 Process complex toolpath functions								
I	Use Computers	I-1 Use computer operating systems	I-2 Understand computer terminology	I-3 Use file management systems	I-4 Install and use software packages									
J	Participate in Total Quality and SPC Activities	J-1 Discuss TQM in manufacturing	J-2 Demonstrate quality problem solving techniques	J-3 Demonstrate knowledge of SPC concepts										
K	Maintain Electrical Devices	K-1 Recognize electrical components	K-2 Use electrical test equipment	K-3 Troubleshoot electrical devices										
L	Maintain Hydraulic/ Pneumatic Devices	L-1 Troubleshoot, maintain, and repair hydraulic systems	L-2 Troubleshoot, maintain, and repair pneumatic systems											

MFO PM6 01/2693

MOLD MAKER .... plans, lays out, sets up, and operates hand and machine tools to perform operations necessary for machining new molds or maintaining/repairing/modifying existing molds to referenced design standards.

Duties	Tasks												
A Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 Lift safely	A-6 Control fire hazards	A-7 MSDS/ Control chemical hazards						
B Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3 Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems	B-9 Perform calculations for sine bar and sine plate	B-10 Calculate for direct, simple, and angular indexing	B-11 Perform calculations necessary for turning tapers	B-12 Use all functions on a scientific calculator	B-13 Calculate draft angles
	B-14 Calculate runner size for molding	B-15 Apply "shrink rate" formulas											
C Interpret Engineering Drawings and Control Documents	C-1 Identify basic layout of drawings	C-2 Identify basic types of drawings	C-3 Review blueprint notes and dimensions	C-4 List the purpose of each type of drawing	C-5 Verify drawing elements	C-6 Practice Geometric Dimensioning and Tolerancing (GD&T)	C-7 Analyze bill of materials (BOM)	C-8 Describe the relationship of engineering drawings to planning	C-9 Understand and use quality systems	C-10 Verify standard requirements			
D Recognize Different Manufacturing Materials and Processes	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Describe the heat treating process	D-4 Test metal samples for hardness	D-5 Understand welding operations	D-6 Evaluate alternative manufacturing processes	D-7 Identify types of plastic materials	D-8 Identify plastic molding processes					
E Measure/ Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/ inspect using surface plate and accessories	E-6 Inspect using stationary equipment							
F Perform Conventional Machining	F-1 Prepare and plan for machining operations	F-2 Use hand tools	F-3 Operate power saws	F-4 Operate drill presses	F-5 Operate vertical milling machines	F-6 Operate horizontal milling machines	F-7 Operate metal cutting lathes	F-8 Operate grinding/ abrasive machines					
G Perform Advanced Machining	G-1 Prepare and plan for CNC machining operations	G-2 Select and use CNC tooling systems	G-3 Program CNC machines	G-4 Operate CNC machining centers (mills)	G-5 Operate CNC turning centers (lathes)	G-6 Program CNC machines using a CAM system	G-7 Download programs via network	G-8 Operate electrical discharge machines					
H Program Using CAM System	H-1 Understand CAD/ CAM programs	H-2 Manipulate CAD functions	H-3 Process simple tool-path data	H-4 Create advanced surface models	H-5 Process complex tool-path functions								
I Use Computers	I-1 Use computer operating systems	I-2 Understand computer terminology	I-3 Use file management systems	I-4 Install and use software packages									
J Build/Repair/ Modify Molds	J-1 Identify types of molds	J-2 Identify typical mold components	J-3 Estimate basic mold cost considerations	J-4 Apply basic mold design principles	J-5 Install mold temperature control devices	J-6 Assemble/ disassemble molds	J-7 Identify "off the shelf" mold components	J-8 Construct a cavity and core for an injection mold	J-9 Build/ assemble/ adjust ejector plates and pins	J-10 Vent molds	J-11 Diagnose and repair all mold related problems	J-12 Polish mold cavities	J-13 Perform preventative maintenance

MLD PM4
02/11/93

TOOL AND DIE MAKER .... skilled workers who produce tools, dies, and special guiding and holding devices that are used in machining.

Duties		Tasks									
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/requirements	A-2 Maintain safe equipment and machinery	A-3 Use safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 Use safe material handling practices	A-6 Consult and apply MSDS for hazards of various materials				
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Perform basic algebraic operations	B-3 Use basic geometric principles	B-4 Perform basic trigonometric functions	B-5 Use and apply Cartesian Coordinate System					
C	Interpret Engineering Drawings and Related Documents	C-1 Interpret and understand basic layout/types of drawings	C-2 Interpret, review, and apply blueprint notes, dimensions, and tolerances	C-3 Use and apply Geometric Dimensioning and Tolerancing (GD&T)	C-4 Demonstrate traditional mechanical drafting and sketching techniques	C-5 Understand and use quality systems					
D	Demonstrate Knowledge of Manufacturing Materials	D-1 Identify materials with desired properties	D-2 Identify materials and processes to produce a part	D-3 Discuss classification systems for metal							
E	Measure/Inspect	E-1 Understand metrology terms	E-2 Select measurement tools	E-3 Measure with hand held instruments	E-4 Eliminate measurement variables	E-5 Measure/inspect using surface plate and accessories	E-6 Inspect using stationary equipment				
F	Demonstrate Knowledge of Manufacturing Processes	F-1 Discuss metal cutting and metal cutting tools	F-2 Operate metal saws	F-3 Operate drill presses and tooling	F-4 Operate engine and turret lathes and tooling	F-5 Operate vertical and horizontal mills and tooling	F-6 Operate precision grinders	F-7 Operate heat treating equipment and processes	F-8 Operate sheet metal equipment	F-9 Operate welding equipment and processes	F-10 Estimate time required/cost to produce a part
G	Use Computers	G-1 Use computer operating systems	G-2 Understand computer terminology	G-3 Use file management systems	G-4 Install and use software packages						
H	Perform CAD/CAM and CNC Programming Tasks	H-1 Discuss fundamentals of CNC machines and controls	H-2 Program and operate CNC milling machine and machining center	H-3 Program and operate CNC lathe	H-4 Use Computer-Aided Drafting (CAD) system	H-5 Create 3-D solid models	H-6 Use Computer-Aided Manufacturing (CAM) system				
I	Perform Tool and Die Making Operations	I-1 Discuss basic types and functions of jigs and fixtures	I-2 Utilize concepts of jig and fixture design	I-3 Demonstrate understanding of different types of industrial dies	I-4 Utilize basic die theory	I-5 Utilize principles of die design	I-6 Perform tool and die repair	I-7 Demonstrate tool and die making skills			
J	Operate Electrical Discharge Machine (EDM)	J-1 Discuss fundamentals of EDM	J-2 Setup and operate conventional sinker EDM	J-3 Program, setup, and operate CNC sinker EDM and EDM drill	J-4 Program, setup, and operate CNC wire EDM						

TLD PM6
022098

WELDER ... that person who is responsible for the planning, layout, fit up of materials, and operation of welding equipment to prepare the work and perform welding operations necessary to produce a work piece to prescribed engineering standards.

Duties	Tasks												
A Follow Safety Practices	A-1 Demonstrate understanding of safety rules	A-2 Assume personal safety standards for self and others	A-3 Describe the purpose and use of protective equipment	A-4 Demonstrate proper handling of hazardous materials	A-5 Demonstrate knowledge of first aid and CPR	A-6 Practice safety precautions when using tools	A-7 Demonstrate proper wearing and use of safety equipment	A-8 Create and maintain a safe work station	A-9 Demonstrate safety precautions regarding ARC flash	A-10 Demonstrate eye safety precautions	A-11 Perform grinding and brushing technique safety	A-12 Maintain adequate ventilation	A-13 Mark "hot-work"
B Total Quality	B-1 Apply principles and tools of continuous quality improvement	B-2 Understand the importance of quality in the manufacturing process	B-3 Implement concepts of quality in the workplace	B-4 Follow the Quality Plan and recommend improvements in work methods or tooling	B-5 Establish methods, plans, and procedures to maintain quality								
C Work Ethics	C-1 Be prompt and on the job in accordance with work schedule	C-2 Value honest work ethics, dedication, and responsibility in the workplace	C-3 Demonstrate high moral values	C-4 Display a neat and clean workplace	C-5 Practice careful use and maintenance of tools and equipment	C-6 Be committed to excellence and quality	C-7 Present a good company image in attire and attitude	C-8 Support a positive work environment	C-9 Practice a positive attitude				
D Communication Skills	D-1 Practice being a good listener	D-2 Demonstrate good reading, comprehension and writing skills	D-3 Document manufacturing processes	D-4 Prepare a recommendation for continuous improvement	D-5 Prepare a summarized priority list of work responsibilities	D-6 Display ability to follow directions, give directions and accept constructive criticism	D-7 Demonstrate positive communication skills with co-workers and supervisors						
E Work as a Team	E-1 Understand the roles of co-workers	E-2 Respect peer relationships	E-3 Share resources to accomplish necessary tasks	E-4 Facilitate the work ethic by completing tasks on time and accurately	E-5 Be involved with problem solving	E-6 Apply creative thinking	E-7 Support a positive attitude	E-8 Encourage good feelings and morale	E-9 Understand purpose and goals of the organization	E-10 Plan and organize work as a team	E-11 Be willing to lead in areas of knowledge and expertise	E-12 Demonstrate willingness to learn new methods and skills	E-13 Demonstrate good personal relations skills
F Mathematical Skills	F-1 Exhibit understanding of basic arithmetic functions	F-2 Exhibit understanding of converting fractions and decimals	F-3 Demonstrate practical mathematics in the use of measurement tools	F-4 Inter-convert Metric/English measurements	F-5 Perform practical mathematical applications relevant to area of work	F-6 Use applied statistics, graphs, and charts for purpose of analysis and problem solving							
G Weld-Related Requirements	G-1 Read job method plan	G-2 Verify and upgrade paperwork	G-3 Interpret drawings and blueprints	G-4 Read welding specifications and procedures									
H Blueprinting, Structural Layout and Fit-Up	H-1 Understand parts of blueprint	H-2 Describe alphabet of lines	H-3 Demonstrate tape reading and measurement techniques	H-4 Use framing square to square parts	H-5 Use level and other devices to verify layout	H-6 Understand and interpret shop drawings for precise layout	H-7 Demonstrate knowledge of welding symbols	H-8 Identify various structural shapes and their respective parts	H-9 Identify structural components and support frameworks of buildings and their components	H-10 Describe proper placement of stiffeners and supports when modifying existing structures	H-11 Identify fillet weld sizes for various thicknesses of base metals	H-12 Describe proper sequence when cutting various shapes to structural drawing specs	H-13 Describe methods for layout slopes and rolling tolerances
	H-14 Describe the use of jigs and fixtures in layout and fit-up	H-15 List the steps to be followed when planning a job	H-16 Interpret structural detail sheets	H-17 Describe methods for straightening and removing damaged structural and machinery parts									
I Set-Up Welding Process(es)	I-1 Gather materials for the job	I-2 Gather welding equipment and tools	I-3 Check welding equipment for safety	I-4 Set-up equipment	I-5 Make test-weld to verify parameters								
J Prepare Joint for Welding	J-1 Prepare joint geometry using mechanical method	J-2 Clean weld area	J-3 Fit-up joint	J-4 Verify joint preparation									
K Oxyacetylene Cutting and Welding	K-1 Identify and describe the function of each piece of equipment	K-2 Identify the safety hazards	K-3 Describe preventive and/or protective measures	K-4 List the welding variables and describe their effects on weld quality	K-5 Describe the AWS oxyfuel gas welding rod classification system	K-6 Describe techniques for preventing or reducing welding related distortion	K-7 Weld mild steel sheet metal using techniques that will minimize the effects of distortion	K-8 List the variables associated with cutting	K-9 Cut mild steel plate in a safe manner				
L1 Shielded Metal Arc Welding (SMAW) (Basic)	L-1 Preheat joint	L-2 Initiate welding process	L-3 Perform weld sequence	L-4 Control weld technique	L-5 Maintain preheat and perform interpass	L-6 Use the carbon arc process to cut and gouge base weld materials	L-7 Apply welders identification	L-8 Control post-weld temperature according to procedures	L-9 Post clean weld	L-10 Post finish weld			
L2 Shielded Metal Arc Welding (SMAW) (Advanced)	L-11 Pass a performance qualification test using SMAW on carbon steel in the 6G position	L-12 Pass a performance qualification test using SMAW on stainless steel pipe in the 6G position											
M1 Gas Metal Arc Welding (GMAW) (Basic)	M-1 Identify GMAW equipment	M-2 Identify the safety hazards	M-3 Describe the preventive and protective measures	M-4 Identify welding variables and their effects upon weld quality	M-5 Troubleshoot equipment	M-6 Describe AWS electrode classification system	M-7 Describe Aluminum Assoc. metal classification system for aluminum alloys	M-8 Describe most common weldability problems associated with aluminum and copper alloys	M-9 GMAW fillet and groove welds on T and butt joints on various metals in various positions	M-10 Demonstrate aluminum GMAW flat horizontal, vertical and overhead	M-11 Describe GMAW filler wires	M-12 Demonstrate ability to repair welds	

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WELDER ... that person who is responsible for the planning, layout, fit up of materials, and operation of welding equipment to prepare the work and perform welding operations necessary to produce a work piece to prescribed engineering standards.

Duties		Tasks												
M2	GMAW Short Circuit Transfer (Intermediate)	M-13 Demonstrate machine adjustments (voltage, amps, wire speed)	M-14 Initiate welding process	M-15 Perform weld sequence	M-16 Control weld technique	M-17 Understand welding characteristics of various shielding gases	M-18 Post-clean weld	M-19 Perform interpass preparation	M-20 Demonstrate short circuit GMAW flat horizontal, vertical and overhead	M-21 Post finish weld	M-22 Describe GMAW filler wires	M-23 Describe basic weld discontinuities		
M3	GMAW Spray and Pulsed Spray, Pipe Transfer (Advanced)	M-24 Demonstrate pre-weld cleaning	M-25 Demonstrate interpass cleaning	M-26 Demonstrate adjustment to pulse and spray transfer machines	M-27 Demonstrate GMAW in flat, horizontal, vertical and overhead positions	M-28 Pre-heat joint, if required; understand joint preparation	M-29 Initiate welding process	M-30 Perform weld sequence	M-31 Describe AISI stainless steels classification system	M-32 Describe weldability problems associated with straight chromium, nickel and stainless steel	M-33 Describe detrimental effects of vibration on the life of piping systems	M-34 Describe methods of minimizing detrimental effects of pressure and heat on life of pipe systems	M-35 Pass a performance qualification test using GMAW on pipe in the 6G position	
N	Flux Core Arc Welding (FCAW)	N-1 Understand the safety factors using FCAW equipment	N-2 Troubleshoot FCAW equipment	N-3 Perform weld sequence	N-4 Shut down FCAW equipment									
O1	Gas Tungsten Arc Welding (GTAW) (Basic)	O-1 Identify GTAW equipment	O-2 Identify the safety standards	O-3 Describe the preventive and protective measures	O-4 Identify the welding variables and their effects upon weld quality	O-5 Troubleshoot equipment	O-6 Describe AWS electrode classification system	O-7 Describe AWS filler metal classification system	O-8 Perform GTAW fillet and groove welds on T and butt joints on various metals in various positions					
O2	Gas Tungsten Arc Welding (GTAW) (Advanced)	O-9 Pass a performance qualification test using GTAW on carbon steel in the 6G position on pipe	O-10 Pass a performance qualification test using GTAW on aluminum in the 6G position on pipe											
P	Plasma Arc Cutting and Welding	P-1 Identify and describe the function of Plasma Arc Cutting (PAC) equipment	P-2 Identify and describe the function of Plasma Arc Welding (PAW) equipment	P-3 Understand the safety factors in Plasma Arc Cutting and Plasma Arc Welding processes	P-4 Set-up Plasma Arc Cutting equipment	P-5 Set-up Plasma Arc Welding equipment	P-6 Perform Plasma Arc Cutting and Plasma Arc Welding on various materials	P-7 Perform shut down procedures on Plasma Arc Cutting and Plasma Arc Welding equipment						
Q	In-Process Weld Inspection	Q-1 Check weld size	Q-2 Perform visual inspection											
R	In-Process Rework	R-1 Remove weld defect and prepare for reweld	R-2 Verify defect removal	R-3 Pre-heat weld (if required)	R-4 Perform reweld	R-5 Repeat in-process inspection								
S	Housekeeping Activities	S-1 Return unused consumables	S-2 Store tools	S-3 Secure welding equipment	S-4 Secure welding gases	S-5 Clean work area(s)								
T	Emergency Vehicle Terminology	T-1 Display a general understanding of emergency vehicle terminology	T-2 Understand the functions of equipment being assembled	T-3 Understand how components relate as a total system										
U	Wellness/Physical Abilities	U-1 Demonstrate ability to lift 50 pounds	U-2 Demonstrate ability to tolerate heights up to 100 feet	U-3 Ability to work from various positions while standing on concrete for extended periods	U-4 Display ability to work in hot/cold environment for 8-10 hours	U-5 Present a history of documented regular attendance at work	U-6 Apply wellness information to lifestyle to maintain health							

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Resources
The MASTER Training Modules are available in printed form, on CD-ROM and on the Internet at http://machinetool.tstc.edu.

The MASTER consortium of member colleges that have developed the Training Modules covers the major geographic regions of the nation. Each member is available to provide additional information and resource as might be required.

Augusta Technical Institute
Center for Advanced Technology (CAT)
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Augusta, GA 30906
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Phone: 706-771-4089
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San Diego City College
Center for Applied Competitive Technologies (CACT)
1313 Twelfth Avenue
San Diego, CA 92101
Dr. Joan A. Stepsis - Dean/Director, CACT
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E-Mail: jstepsis@sdccd.cc.ca.us

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E-Mail: chrestmn@icc.cc.ms.us

Moraine Valley Community College
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10900 South 88th Avenue
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Dr. Richard Hinckley - Dean of Instruction, Workforce Development & Community Service
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Springfield Technical Community College
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MACHINIST.... plan, layout, set up, and operate hand and machine tools to perform machining operations necessary to produce a workpiece to referenced engineering standards.

Duties		Tasks												
A	Practice Safety	A-1 Follow safety manuals and all safety regulations/ requirements	A-2 Use protective equipment	A-3 Follow safe operating procedures for hand and machine tools	A-4 Maintain a clean and safe work environment	A-5 Lift safely	A-6 MSDS/ Control chemical hazards							
B	Apply Mathematical Concepts	B-1 Perform basic arithmetic functions	B-2 Convert fractions/ decimals	B-3Convert Metric/ English measurements	B-4 Perform basic algebraic operations	B-5 Use practical geometry	B-6 Understand basic trigonometry	B-7 Calculate speeds and feeds for machining	B-8 Use coordinate systems	B-9 Perform calculations for sine bar and sine plate	B-10Calculate for direct, simple, and angular indexing	B-11 Perform calculations necessary for turning tapers	B-12Calculate depth of cut for round surfaces	
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MAC-G3

MACHINIST SERIES

MASTER Technical Module No. MAC-G3

Subject: **Conventional Machining** **Time: 30 Hrs.**

Duty: **Perform Advanced Machining**
Task: Program CNC Machines

Objective(s):

Upon completion of this unit the student will be able to:

a. Identify and describe essentials and safety of CNC systems;
b. Identify and describe types of CNC hardware and software;
c. Identify and describe machine axes and coordinate systems;
d. Identify and describe coordinate systems;
e. Plan and write programs for CNC mills; and,
f. Plan and write programs for CNC lathes.

Instructional Materials:

MASTER Handout (MAC-G3-HO)
MASTER Laboratory Exercise (MAC-G3-LE)
MASTER Laboratory Aid (MAC-G3-LA)
MASTER Self-Assessments (two)

References:

Computer Numerical Control, From Programming to Networking, S. C. Jonathan Lin, Delmar Publishers Inc., Latest Edition

Student Preparation:

Students should have previously completed the following Technical Modules:
MAC-G1 "Prepare and Plan for CNC Machining Operations"
MAC-G2 "Select and Use CNC Tooling Systems"

Introduction:

In the modern world of machining more and more companies are relying heavily on CNC machinery. This is a trend that is expected to continue into the future of Machine Technology. Many students are highly motivated to learn how to program and operate this type of equipment. It is wise to have a basic understanding of how the equipment functions so we can have a better understanding of how to program the machine tool operations. Many of the procedures can be compared directly to their conventional machine counterparts. Most people will progress further along if they establish a solid foundation in the basic principles.

Presentation Outline:

I. Identify and Describe Essentials and Safety of CNC Systems
    A. Identify and explain essentials
        1. Define numerical control
        2. Explain history and future of CNC technology
        3. Identify basic elements of CNC system
        4. Define Computer Numerical Control (CNC)
        5. Explain advantages and limitations of CNC
        6. Identify applications of CNC technology
    B. Compare types of CNC systems
        1. Identify and describe modes on numerical control systems
        2. Explain difference between the following:
            a. Point-to-point
            b. Axial path
            c. 45° line type
            d. Linear Path
            e. Continuous path
        3. Describe CNC interpolation
        4. Identify types of CNC interpolations
        5. Explain difference between open loop and closed loop systems
        6. List benefits and problems of open and closed loop systems
    C. Demonstrate safety practices related to CNC systems
        1. Demonstrate safety practices, including:
            a. Safety guard/door interlocks
            b. Power box interlocks
            c. Tool loading and unloading
            d. Loading and unloading work holding devices
            e. Machine coolant disposal
        2. Describe/identify personal safety equipment
II. Identify and Describe Types of CNC Hardware and Software
    A. Identify and describe CNC hardware
        1. Compare NC and CNC systems
        2. Identify components of CNC machine control unit (MCU)
        3. Define applications of operator control panel
        4. Explain functions of operator control panel
        5. Define utilities found on typical control panel
        6. Select appropriate CNC controls
    B. Describe CNC software

1. Describe software related to machine tool
2. Describe applications of operation, interface and application software
3. Describe interface of software and hardware

C. Explain feed back drive system
1. Describe feed drive system
2. Explain feed back mechanisms
3. Compare direct and indirect measurement systems

III. Identify and Describe Machine Axes and Coordinate Systems

A. Identify and describe machine axes
1. Define and identify machine axes X, Y and Z
2. Identify and describe linear axes using right hand rule
3. Identify and define primary rotary axes a, b and c

B. Describe coordinate systems
1. Describe Cartesian coordinate system as used in NC program
2. Define relationship of Cartesian coordinate system with machine axes

C. Define characteristics of positioning systems
1. Define application of absolute positioning systems
2. Define application of incremental positioning systems

D. Define reference systems
1. Describe characteristics of:
   a. Machine reference coordinates
   b. Work reference coordinates
   c. Program reference coordinates
   d. Fixtures offset coordinates

IV. Describe and Interpret CNC Coding Systems

A. Interpret number bases
1. Interpret decimal and binary bases
2. Interpret octal and hexadecimal bases

B. Describe NC program storage media
1. Describe the media
2. Describe advantages and disadvantages of each media

C. Describe EIA and ASCII formatted tapes
1. Describe EIA format on tapes
2. Describe ASCII format on tapes
3. Describe differences in EIA and ASCII formats

V. Write NC Programs

A. Create NC words
1. Define NC characters, blocks and words
2. Identify and describe commonly used NC codes
3. Describe and create safe start blocks
4. Combine NC codes to create part program

B. Create NC programs
1. Use absolute (G90) and incremental (G91) positioning

2. Use rapid positioning (G00) and linear interpolation (G01)
3. Use circular interpolation (G02) and (G03)
4. Identify plane selections (G17, G18, G19)
5. Apply proper plane selection to circular interpolation
6. Define and describe axis modifiers (I, J, K) and apply to circular interpolation (absolute and incremental type)

C. Calculate and program cutter speed and cutter compensation
1. Describe cutter compensation commands (G40, G41, G42)
2. Describe relationships associated with G41 and climb milling
3. Describe relationship associated with G42 and conventional milling
4. Evaluate reference documentation to establish machinability factors for RPM equation
5. Apply RPM calculations to identify proper spindle speed "S" word

D. Calculate and program cutter feed and depth of cut
1. Evaluate reference documentation to establish feed rate factors
2. Apply depth of cut calculations for programming efficiency
3. Apply feed equation to establish correct feed "F" word

E. Program tool selection and unit input systems
1. Describe and apply unit input code (G70 and G71) correctly
2. Describe tool function "T" word and its use
3. Describe retract quill to Z machine home "M6"
5. Describe and apply "T" word with "M6" to create tool change
6. Apply "M" codes to program
7. Describe and list common "M" words and their applications
8. Describe "M00" program stop and "M01" optional stop applications
9. Describe "M02" end of program and "M30" end of tape

F. Program spindle operation
1. Identify spindle commands
2. Describe "M03" spindle on clockwise and "M04" spindle on counterclockwise
3. Describe "M05" stop spindle
4. Identify and describe coolant commands "M07", "M08" and "M09"
5. Apply "M" codes to program

G. Program fixed cycles
1. Identify and describe fixed cycles "G81 - G89"
2. Describe benefits and time saving by using fixed cycles in programming
3. Explain different fixed cycle formats for different controllers
4. Apply fixed cycles to programs

H. Program operator messages
1. Identify and describe non-machine code "operator messages"

2. Describe symbols to isolate operator messages from program
    a. "*"
    b. "( )"
3. Apply operator messages to NC part program as needed

VI. Student Practice - Plan and Write Programs for CNC Mills

VII. Student Practice - Plan and Write Programs for CNC Lathes

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Practical Application:

Students should complete CNC programming exercises for the CNC mill and the CNC lathe.

Evaluation and/or Verification:

Students should successfully complete the Self-Assessment found at the end of this lesson.

Summary:

Review the main lesson points and answer student questions.

Next Lesson Assignment:

MASTER Technical Module (MAC-G4) dealing with operating CNC machining centers (mills).

MAC-G3-HO
Program CNC Machines
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
a. Identify and describe essentials and safety of CNC systems;
b. Identify and describe types of CNC hardware and software;
c. Identify and describe machine axes and coordinate systems;
d. Identify and describe coordinate systems;
e. Plan and write programs for CNC mills; and,
f. Plan and write programs for CNC lathes.

Module Outline:

I. Identify and Describe Essentials and Safety of CNC Systems
   A. Identify and explain essentials
      1. Define numerical control
      2. Explain history and future of CNC technology
      3. Identify basic elements of CNC system
      4. Define Computer Numerical Control (CNC)
      5. Explain advantages and limitations of CNC
      6. Identify applications of CNC technology
   B. Compare types of CNC systems
      1. Identify and describe modes on numerical control systems
      2. Explain difference between the following:
         a. Point-to-point
         b. Axial path
         c. 45° line type
         d. Linear Path
         e. Continuous path
      3. Describe CNC interpolation
      4. Identify types of CNC interpolations
      5. Explain difference between open loop and closed loop systems
      6. List benefits and problems of open and closed loop systems
   C. Demonstrate safety practices related to CNC systems
      1. Demonstrate safety practices, including:
         a. Safety guard/door interlocks
         b. Power box interlocks
         c. Tool loading and unloading
         d. Loading and unloading work holding devices
         e. Machine coolant disposal
      2. Describe/identify personal safety equipment

II. Identify and Describe Types of CNC Hardware and Software
  A. Identify and describe CNC hardware
    1. Compare NC and CNC systems
    2. Identify components of CNC machine control unit (MCU)
    3. Define applications of operator control panel
    4. Explain functions of operator control panel
    5. Define utilities found on typical control panel
    6. Select appropriate CNC controls
  B. Describe CNC software
    1. Describe software related to machine tool
    2. Describe applications of operation, interface and application software
    3. Describe interface of software and hardware
  C. Explain feed back drive system
    1. Describe feed drive system
    2. Explain feed back mechanisms
    3. Compare direct and indirect measurement systems

III. Identify and Describe Machine Axes and Coordinate Systems
  A. Identify and describe machine axes
    1. Define and identify machine axes X, Y and Z
    2. Identify and describe linear axes using right hand rule
    3. Identify and define primary rotary axes a, b and c
  B. Describe coordinate systems
    1. Describe Cartesian coordinate system as used in NC program
    2. Define relationship of Cartesian coordinate system with machine axes
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    1. Describe characteristics of:
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    2. Describe ASCII format on tapes

3. Describe differences in EIA and ASCII formats

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  1. Identify and describe non-machine code "operator messages"
  2. Describe symbols to isolate operator messages from program
     a. "*"
     b. "( )"
  3. Apply operator messages to NC part program as needed

VI. Student Practice - Plan and Write Programs for CNC Mills

VII. Student Practice - Plan and Write Programs for CNC Lathes

The students shall:

a. Plan and write programs for CNC mills; and,

b. Plan and write programs for CNC lathes.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
    a. No loose clothing, including ties;
    b. Long hair properly stowed;
    c. No jewelry;
    d. Hard, closed-toe shoes;
    e. Eye protection (safety glasses); and,
    f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

Name: ____________________ Date: ____________________

MAC-G3
Program CNC Machines
Self-Assessment No. 1

Circle the letter preceding the correct answer.

1. The definition "a system in which actions are controlled by the insertion of numerical data at some point" refers to?
   a. Direct Numerical Control
   b. Distributive Numerical Control
   c. Numerical Control
   d. Computerized Numerical Control

2. Which company is given credit for creating the first numerical control milling machine?
   a. Rohr Industries
   b. Massachusetts Institute of Technology
   c. Parsons corporations
   d. General Electric

3. The term CNC stands for?
   a. Continuous Numerical Control
   b. Centerline Numerical Control
   c. Computerized Numerical Control
   d. Computerized Numerical Counter

4. The term DNC has multiple definitions one is:
   a. Distinct numerical control
   b. Desired numerical control
   c. Direct numerical control
   d. Destination numerical control

5. The term DNC has multiple definitions another one is:
   a. District numerical control
   b. Distributive numerical control
   c. Distinctive numerical control
   d. Desired numerical control

6. Examples of basic elements of a CNC system would include;
   a. Center drill
   b. Milling cutters
   c. Mouse
   d. Part program

7. Examples of basic elements of a CNC system would include;
   a. Anilam
   b. Program input device
   c. Pocket calculator
   d. Coolant

8. Examples of basic elements of a CNC system would include;
   a. Machine control unit
   b. Outside micrometer
   c. Pencil and paper
   d. Basic understanding of mathematics

9. Examples of basic elements of a CNC system would include;
   a. Barcoding system
   b. Inside micrometer
   c. Drive systems
   d. Basic understanding of engineering drawings

10. Examples of basic elements of a CNC system would include;
    a. Machine Tool
    b. Basic theory of metal removal
    c. Dial calipers
    d. Windows operating system

11. Examples of basic elements of a CNC system would include;
    a. Clamping devices
    b. Depth micrometers
    c. Feedback systems
    d. Fine surface finishes

12. NC Systems are often referred to as:
    a. Primary memory
    b. Softwired
    c. Hardwired
    d. Secondary memory

13. CNC Systems are often referred to as:
    a. Primary memory
    b. Softwired
    c. Hardwired
    d. Secondary memory

14. Examples of advantages of CNC would include:
    a. High cost of cutting tools
    b. Increased productivity
    c. Highly attractive machines
    d. More interesting for maintenance workers

15. Examples of advantages of CNC would include:
    a. Lower number of pallets needed
    b. Increased electronics
    c. Inch and metric calibrations
    d. High accuracy and repeatability

16. Examples of advantages of CNC would include:
    a. Reduced production costs
    b. Systems require less attention
    c. Cost effective for small production runs
    d. Lower maintenance requirements

17. Examples of advantages of CNC would include:
    a. Reduced initial investment
    b. Reduced indirect operating costs
    c. Cost effective for small production runs
    d. Lower maintenance requirements

18. CNC operators have to have a higher skill level then a precision tool maker.
    a. True
    b. False

19. Examples of disadvantages (limitations) of CNC would include:
    a. High cost of cutting tools
    b. Higher productivity
    c. High initial investment
    d. High probability of human error

20. Examples of disadvantages (limitations) of CNC would include:
    a. Higher scrap rates
    b. Higher Maintenance requirements
    c. Higher machine utilization
    d. High probability of human error

21. Examples of disadvantages (limitations) of CNC would include:
    a. Not cost effective for precision parts
    b. Not cost effective for alloys
    c. Not cost effective for low production levels
    d. Not cost effective for non ferrous metals

22. CNC can only be applied to applications of chip removal.
    a. True
    b. False

23. The addition of CNC Machines guarantees increased productivity.
    a. True
    b. False

24. CNC programming has been dramatically changed by the advent of:
    a. Fiber optics
    b. CAD/CAM
    c. Space age coolants
    d. Special applications

25. The point to point control system is most often used in ________________ operations.
    a. Rough machining
    b. Pocket machining
    c. Drilling
    d. Contouring

26. The continuous-path control system is often called ________________ system.
    a. Rough machining
    b. Pocket machining
    c. Drilling
    d. Contouring

27. The continuous-path control system is limited since it can only move one axis at a time.
    a. True
    b. False

28. An example of a function of the CNC interpolator would include:
    a. Generates spindle speed calculations for efficient material removal
    b. Generates intermediate coordinate positions along the program path
    c. Generates the proper feed rate in program
    d. Generates a complete list of "G" codes as needed by the machine

29. An example of a function of the CNC interpolator would include:
    a. Computes coolant selections for machine tool as needed
    b. Computes separate tool changes as needed
    c. Computes individual axis velocities as needed
    d. Computes material finish requirements as needed

30. One example of a common interpolation would be:
    a. Metabolic
    b. Bi cubic approximation
    c. Linear
    d. Helical cubic NURB

31. One example of a common interpolation would be:
    a. Eliptoidinal
    b. Bi nurdic eliptoidinal
    c. Radius
    d. Circular

32. One significant feature of the _______________ control system is that there is no feedback signal for checking whether the programmed position has been reached.
    a. Closed loop
    b. Open loop
    c. NC
    d. CNC

33. One significant feature of the _______________ control system is that there are feedback signals that check whether the programmed position has been reached.
    a. Closed loop
    b. Open loop
    c. NC
    d. CNC

34. The _______________ control system is usually used with the point to point systems.
    a. Closed loop
    b. Open loop
    c. NC
    d. CNC

35. The __________________ control system is usually used with continuous path systems.
    a. Closed loop
    b. Open loop
    c. NC
    d. CNC

36. The acronym MCU stands for:
    a. Machine Companies Unification
    b. Machine control unit
    c. Machine control university
    d. Machine control union

37. An example of primary memory would include:
    a. Floppy disks
    b. Hard drives
    c. RAM
    d. Paper tape

38. An example of primary memory would include:
    a. Greco system
    b. DNC
    c. ROM
    d. Punch cards

39. An example of secondary memory would include:
    a. Greco system
    b. DNC
    c. ROM
    d. Hard drives

40. An example of secondary memory would include:
    a. Floppy disks
    b. Greco system
    c. RAM
    d. Paper tape

41. Machine ______________ is what allows us to reach a exact desired point coordinate.
    a. Controller
    b. Repeatability
    c. Accuracy
    d. Programming

42. Machine ______________ is what allows us to come back to an exact point coordinate time after time.
    a. Controller
    b. Repeatability
    c. Accuracy
    d. Programming

43. The ________________ measurement feedback system is free from the effects of machine backlash.
   a. Indirect
   b. Direct
   c. Closed loop
   d. Open loop

44. The ________________ measurement feedback system is affected by machine backlash.
   a. Indirect
   b. Direct
   c. Closed loop
   d. Open loop

45. The ________________ measurement feedback system is more accurate.
   a. Indirect
   b. Direct
   c. Closed loop
   d. Open loop

46. The machine axis designation by X, Y, and Z are the ______________ machine axis.
   a. Tertiary linear
   b. Primary linear
   c. Secondary linear
   d. Primary rotary

47. The machine axis designation by A, B and C are the ________________ machine axis.
   a. Tertiary linear
   b. Primary linear
   c. Secondary linear
   d. Primary rotary

48. The Cartesian coordinate system is often referred to as the ________________ coordinate system.
   a. Polar
   b. Secondary
   c. Rectangular
   d. Primary

49. The data point X -1.0, Y -2.0 is located in the number _______________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

50. The data point X 1.0, Y 2.0 is located in the number _______________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

51. The data point X 1.0, Y -2.0 is located in the number _______________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

52. The data point X -1.0, Y 2.0 is located in the number _______________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

53. The _______________ coordinate system defines the position of a point by its radius and an angle of rotation.
   a. Polar
   b. Secondary
   c. Rectangular
   d. Primary

54. If a data point was rotated 100 degrees from 0 it would be in the number ____________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

55. If a data point was rotated 295 degrees from 0 it would be in the number ____________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

56. If a data point was rotated 40 degrees from 0 it would be in the number ____________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

57. If a data point was rotated 195 degrees from 0 it would be in the number ____________ quadrant.
   a. 1
   b. 2
   c. 3
   d. 4

58. In the ______________ positioning system all positions are measured from a single fixed point.
   a. Incremental
   b. Polar
   c. Rectangular
   d. Absolute

59. In the ______________ positioning system, the reference point is not fixed and moves from data point to data point.
   a. Incremental
   b. Polar
   c. Rectangular
   d. Absolute

MAC-G3
Program CNC Machines
Self-Assessment No. 1 Answer Key

1.	D	31.	D
2.	C	32.	B
3.	C	33.	A
4.	C	34.	B
5.	B	35.	A
6.	D	36.	B
7.	B	37.	C
8.	A	38.	C
9.	C	39.	D
10.	A	40.	A
11.	C	41.	C
12.	C	42.	B
13.	B	43.	B
14.	B	44.	A
15.	D	45.	B
16.	A	46.	B
17.	B	47.	B
18.	B	48.	C
19.	C	49.	C
20.	B	50.	A
21.	C	51.	D
22.	B	52.	B
23.	B	53.	A
24.	B	54.	B
25.	C	55.	B
26.	D	56.	A
27.	B	57.	C
28.	B	58.	D
29.	C	59.	A
30.	C		

MAC-G3
Program CNC Machines
Self-Assessment No. 2

1. The command "G01" is an example of a NC ____________.
   a. Address
   b. Word
   c. Block
   d. Program

2. In the command "G01" the G is an example of a NC ______________.
   a. Address
   b. Word
   c. Block
   d. Program

3. "N01 G90 G80 G17" would be an example of a NC ____________.
   a. Address
   b. Word
   c. Block
   d. Program

4. A complete set of codes that would make a part would be called a(n) ___________.
   a. Address
   b. Word
   c. Block
   d. Program

CNC PROGRAMMING
Commonly used "G" and "M" Codes and Miscellaneous Codes

5. G91:
   a. Height (tool length offset)
   b. X, Y plane selection
   c. Set X, Y, Z values, reset values
   d. Incremental programming
   e. Drill with dwell at end of "z" travel

6. G81:
   a. Fast rapid positioning move
   b. Optional stop, acts as M00 or disappears
   c. Common drill cycle
   d. Reaming cycle, stops spindle at "z" depth
   e. Drill with dwell at end of "z" travel

7. G71:
   a. Incremental programming
   b. Metric programming
   c. Set X, Y, Z values, reset values
   d. Reaming cycle, stops spindle at "z" depth
   e. Drill with dwell at end of "z" travel

8. M06:
   a. Spindle on clockwise
   b. Spindle on counter clock
   c. Machine stop, stops everything
   d. Retract spindle to home position
   e. Kills canned cycles

9. G02:
   a. Counter clockwise arc requires axis modifiers
   b. Straight line move requires feed rate
   c. Set X, Y, Z values, reset values
   d. Cutter compensation left
   e. Clockwise arc requires axis modifiers

10. "S":
   a. Fast rapid positioning move
   b. Straight line move requires feed rate
   c. X axis modifier
   d. Spindle stop
   e. Speed

11. M00:
   a. Kill coolant
   b. Set X, Y, Z values, reset values
   c. Optional stop, acts as M00 or disappears
   d. Machine stop, stops everything
   e. Spindle stop

12. G04:
   a. X, Y axis movement
   b. Dwell
   c. Set X, Y, Z values, reset values
   d. Spindle stop
   e. Commonly stands for tool

13. G19:
    a. X, Y axis movement
    b. X, Y plane selection
    c. X, Z plane selection
    d. X, Z axis movement
    e. Y, Z plane selection

14. G00:
    a. Fast rapid positioning move
    b. Bore in and out
    c. Machine stop, stops everything
    d. Cutter compensation left
    e. Cancels cutter compensation

15. "I":
    a. Incremental programming
    b. Z axis modifier
    c. X axis modifier
    d. Mist coolant
    e. Y, Z plane selection

16. G40:
    a. Counter clockwise arc requires axis modifiers
    b. Spindle on counter clock
    c. Kill coolant
    d. Kills cutter compensation
    e. Kills canned cycles

17. M01:
    a. Incremental programming
    b. Optional stop, acts as M00 or disappears
    c. End of program, stop
    d. Mist coolant
    e. Cutter compensation right

18. M08:
    a. Spindle on clockwise
    b. Mist coolant
    c. Peck cycle, deep hole drilling
    d. Flood coolant
    e. Clockwise arc requires axis modifiers

19. G03:
    a. Straight line move requires feed rate
    b. Common drill cycle
    c. Clockwise arc requires axis modifiers
    d. Cutter compensation right
    e. Counter clockwise arc requires axis modifiers

20. G41:
    a. Height (tool length offset)
    b. Z axis modifier
    c. End of program, stop
    d. Cutter compensation left
    e. Cutter compensation right

21. M04:
    a. Spindle on clockwise
    b. Dwell
    c. Machine stop, stops everything
    d. Spindle on counter clockwise
    e. Spindle stop

22. G42:
    a. Counter clockwise arc requires axis modifiers
    b. Optional stop, acts as M00 or disappears
    c. Peck cycle, deep hole drilling
    d. Cutter compensation left
    e. Cutter compensation right

23. M09:
    a. Counter clockwise arc requires axis modifiers
    b. Spindle on counter clock
    c. Kill coolant
    d. Kills cutter compensation
    e. Kills canned cycles

24. G70:
    a. Incremental programming
    b. Metric programming
    c. Set X, Y, Z values, reset values
    d. Inch programming
    e. Drill with dwell at end of "z" travel

25. "F":
  a. Fast rapid positioning move
  b. Feed
  c. Common drill cycle
  d. Flood coolant
  e. Offset number (tool diameter)

26. M02:
  a. Spindle on clockwise
  b. Spindle on counter clockwise
  c. End of program, stop
  d. End of program, return to beginning of program and wait
  e. Cutter compensation right

27. G80:
  a. Counter clockwise arc requires axis modifiers
  b. Spindle on counter clock
  c. Kill coolant
  d. Kills cutter compensation
  e. Kills canned cycles

28. G82:
  a. Common mill cycle
  b. Bore in and out
  c. Peck cycle, deep hole drilling
  d. Reaming cycle, stops spindle at "z" depth
  e. Drill with dwell at end of "z" travel

29. G01:
  a. Fast rapid positioning move
  b. Straight line move requires feed rate
  c. Set X, Y, Z values, reset values
  d. Reaming cycle, stops spindle at "z" depth
  e. X, Z axis movement

30. G83:
  a. Common drill cycle
  b. Reaming cycle, stops spindle at "z" depth
  c. Peck cycle, deep hole drilling
  d. Reaming cycle, stops spindle at "z" depth
  e. Drill with dwell at end of "z" travel

31. G17:
   a. X, Y axis movement
   b. X, Y plane selection
   c. X, Z plane selection
   d. X, Z axis movement
   e. Y, Z plane selection

32. "J":
   a. Height (tool length offset)
   b. Z axis modifier
   c. Y axis modifier
   d. Z axis modifier
   e. Y, Z plane selection

33. M03:
   a. Spindle on clockwise
   b. Dwell
   c. End of program, stop
   d. Spindle stop
   e. Clockwise arc requires axis modifiers

34. G90:
   a. Incremental programming
   b. Metric programming
   c. X, Z plane selection
   d. Absolute programming
   e. Cancels cutter compensation

35. M05:
   a. Spindle on clockwise
   b. Dwell
   c. Machine stop, stops everything
   d. Spindle stop
   e. Cancels cutter compensation

36. M07:
   a. Spindle on clockwise
   b. Mist coolant
   c. Peck cycle, deep hole drilling
   d. Flood coolant
   e. Clockwise arc requires axis modifiers

37. M30:
   a. Spindle on clockwise
   b. Spindle on counter clockwise
   c. End of program, stop
   d. End of program, return to beginning of program and wait
   e. Cutter compensation right

38. "T":
   a. Height (tool length offset)
   b. Feed
   c. End of program, stop
   d. Mist coolant
   e. Commonly stands for tool

39. G18:
   a. X, Z plane movement
   b. X, Z plane selection
   c. Y, Z plane selection
   d. Y, Z axis movement
   e. X, Z axis movement

40. "K":
   a. X axis modifier
   b. Z axis modifier
   c. Y axis modifier
   d. X, Z plane selection
   e. Y, Z plane selection

41. "H":
   a. Height (tool length offset)
   b. Feed
   c. Y axis modifier
   d. Retract spindle to home position
   e. Speed

42.-
43. In the ____________ (answer to #42) positioning system, all points are measured from a fixed point or origin, and it's "G" code is __________ (answer to #43).

42.
   a. absolute
   b. incremental
   c. fast rapid position move
   d. set X,Y,Z values, reset values.

43.
   a. G91
   b. G92
   c. G90
   d. G00

44.-
45. In the ___________ (answer to # 44) positioning system, the reference point from which the dimensions are measured is not fixed. Instead, it moves to the immediate preceding point from operation to operation. It's "G" code is ___________ (answer to #45).

44.
a. absolute
b. incremental
c. fast rapid position move
d. set X,Y,Z values, reset values.

45.
a. G91
b. G92
c. G90
d. G00

46. What is the formula for calculating spindle speeds for CNC machining in revolutions per minute?
a. RPM = Pi x D divided by CS x 12
b. RPM = CS x 12 divided by Pi x D
c. RPM = CS x 4 divided by Pi
d. None; automatically set with MDI on the CNC machine.

47. What is the formula for calculating feeds for CNC machining in inches per minute?
a. IPM = Pi x D divided by CS x 12
b. IPM = number of teeth on cutter x chip load per tooth
c. None; geometry set with MDI on the CNC machine.
d. IPM = RPM x number of teeth on cutter x chip load per tooth

48. If we saw the command G41D1 in a CNC program, we would know to check the ______________.
a. Cutter diameter in offset number 41
b. Cutter diameter in offset number G41D
c. Cutter diameter in offset number 1
d. Cutter diameter in offset number sl,1

Calculate the following RPM's and feed rates. Use your calculator and set for 3 decimal places.

	CS	DIA.	RPM	IPM =	CPT	# of Teeth
49.	250	.125	_____	_____	.002	4
50.	300	1.250	_____	_____	.0125	15
51.	325	.875	_____	_____	.003	2
52.	25	.500	_____	_____	.006	3
53.	100	.187	_____	_____	.001	6

Answer selection for the above questions. (RPM's / IPM's)

49. a. 8000.000 / 64.000
    b. 7639.437 / 61.115
    c. 119.366 / 0.955

50. a. 916.732 / 171.887
    b. 1432.394 / 268.574
    c. 960.000 / 180.000

51. a. 1418.753 / 8.513
    b. 2.749 / 0.016
    c. 1485.714 / 8.914

52. a. 2000.000 / 3.600
    b. 190.986 / 3.438
    c. 1884.956 / 33.929

53. a. 20159.953 / 120.960
    b. 2139.037 / 12.834
    c. 2042.630 / 12.256

MAC-G3

Program CNC Machines

Self-Assessment No. 2 Answer Key

1.	B	31.	B
2.	A	32.	C
3.	C	33.	A
4.	D	34.	D
5.	D	35.	D
6.	C	36.	B
7.	B	37.	D
8.	D	38.	E
9.	E	39.	B
10.	E	40.	B
11.	D	41.	A
12.	B	42.	A
13.	E	43.	C
14.	A	44.	B
15.	C	45.	A
16.	D	46.	B
17.	B	47.	D
18.	D	48.	C
19.	E	49.	B
20.	D	50.	A
21.	D	51.	A
22.	E	52.	B
23.	C	53.	C
24.	D		
25.	B		
26.	C		
27.	E		
28.	E		
29.	B		
30.	C		

MACHINE TOOL ADVANCED SKILLS TECHNOLOGY EDUCATIONAL RESOURCES

MASTER

a consortium of educators and industry

EDUCATIONAL RESOURCES
FOR THE
MACHINE TOOL INDUSTRY

Machining Series
STUDENT LABORATORY MANUAL

Supported by the National Science Foundation's Advanced Technological Education Program

MAC-G3-HO
Program CNC Machines
Attachment 1: **MASTER** Handout

Objective(s):

Upon completion of this unit the student will be able to:
a. Identify and describe essentials and safety of CNC systems;
b. Identify and describe types of CNC hardware and software;
c. Identify and describe machine axes and coordinate systems;
d. Identify and describe coordinate systems;
e. Plan and write programs for CNC mills; and,
f. Plan and write programs for CNC lathes.

Module Outline:

I. Identify and Describe Essentials and Safety of CNC Systems
  A. Identify and explain essentials
    1. Define numerical control
    2. Explain history and future of CNC technology
    3. Identify basic elements of CNC system
    4. Define Computer Numerical Control (CNC)
    5. Explain advantages and limitations of CNC
    6. Identify applications of CNC technology
  B. Compare types of CNC systems
    1. Identify and describe modes on numerical control systems
    2. Explain difference between the following:
      a. Point-to-point
      b. Axial path
      c. 45° line type
      d. Linear Path
      e. Continuous path
    3. Describe CNC interpolation
    4. Identify types of CNC interpolations
    5. Explain difference between open loop and closed loop systems
    6. List benefits and problems of open and closed loop systems
  C. Demonstrate safety practices related to CNC systems
    1. Demonstrate safety practices, including:
      a. Safety guard/door interlocks
      b. Power box interlocks
      c. Tool loading and unloading
      d. Loading and unloading work holding devices
      e. Machine coolant disposal
    2. Describe/identify personal safety equipment

II. Identify and Describe Types of CNC Hardware and Software
  A. Identify and describe CNC hardware
    1. Compare NC and CNC systems
    2. Identify components of CNC machine control unit (MCU)
    3. Define applications of operator control panel
    4. Explain functions of operator control panel
    5. Define utilities found on typical control panel
    6. Select appropriate CNC controls
  B. Describe CNC software
    1. Describe software related to machine tool
    2. Describe applications of operation, interface and application software
    3. Describe interface of software and hardware
  C. Explain feed back drive system
    1. Describe feed drive system
    2. Explain feed back mechanisms
    3. Compare direct and indirect measurement systems

III. Identify and Describe Machine Axes and Coordinate Systems
  A. Identify and describe machine axes
    1. Define and identify machine axes X, Y and Z
    2. Identify and describe linear axes using right hand rule
    3. Identify and define primary rotary axes a, b and c
  B. Describe coordinate systems
    1. Describe Cartesian coordinate system as used in NC program
    2. Define relationship of Cartesian coordinate system with machine axes
  C. Define characteristics of positioning systems
    1. Define application of absolute positioning systems
    2. Define application of incremental positioning systems
  D. Define reference systems
    1. Describe characteristics of:
      a. Machine reference coordinates
      b. Work reference coordinates
      c. Program reference coordinates
      d. Fixtures offset coordinates

IV. Describe and Interpret CNC Coding Systems
  A. Interpret number bases
    1. Interpret decimal and binary bases
    2. Interpret octal and hexadecimal bases
  B. Describe NC program storage media
    1. Describe the media
    2. Describe advantages and disadvantages of each media
  C. Describe EIA and ASCII formatted tapes
    1. Describe EIA format on tapes
    2. Describe ASCII format on tapes

3. Describe differences in EIA and ASCII formats

V. Write NC Programs

A. Create NC words
1. Define NC characters, blocks and words
2. Identify and describe commonly used NC codes
3. Describe and create safe start blocks
4. Combine NC codes to create part program

B. Create NC programs
1. Use absolute (G90) and incremental (G91) positioning
2. Use rapid positioning (G00) and linear interpolation (G01)
3. Use circular interpolation (G02) and (G03)
4. Identify plane selections (G17, G18, G19)
5. Apply proper plane selection to circular interpolation
6. Define and describe axis modifiers (I, J, K) and apply to circular interpolation (absolute and incremental type)

C. Calculate and program cutter speed and cutter compensation
1. Describe cutter compensation commands (G40, G41, G42)
2. Describe relationships associated with G41 and climb milling
3. Describe relationship associated with G42 and conventional milling
4. Evaluate reference documentation to establish machinability factors for RPM equation
5. Apply RPM calculations to identify proper spindle speed "S" word

D. Calculate and program cutter feed and depth of cut
1. Evaluate reference documentation to establish feed rate factors
2. Apply depth of cut calculations for programming efficiency
3. Apply feed equation to establish correct feed "F" word

E. Program tool selection and unit input systems
1. Describe and apply unit input code (G70 and G71) correctly
2. Describe tool function "T" word and its use
3. Describe retract quill to Z machine home "M6"
5. Describe and apply "T" word with "M6" to create tool change
6. Apply "M" codes to program
7. Describe and list common "M" words and their applications
8. Describe "M00" program stop and "M01" optional stop applications
9. Describe "M02" end of program and "M30" end of tape

F. Program spindle operation
1. Identify spindle commands
2. Describe "M03" spindle on clockwise and "M04" spindle on counterclockwise
3. Describe "M05" stop spindle
4. Identify and describe coolant commands "M07", "M08" and "M09"

5. Apply "M" codes to program

G. Program fixed cycles
   1. Identify and describe fixed cycles "G81 - G89"
   2. Describe benefits and time saving by using fixed cycles in programming
   3. Explain different fixed cycle formats for different controllers
   4. Apply fixed cycles to programs

H. Program operator messages
   1. Identify and describe non-machine code "operator messages"
   2. Describe symbols to isolate operator messages from program
      a. "*"
      b. "( )"
   3. Apply operator messages to NC part program as needed

VI. Student Practice - Plan and Write Programs for CNC Mills

VII. Student Practice - Plan and Write Programs for CNC Lathes

The students shall:

a. Plan and write programs for CNC mills; and,
b. Plan and write programs for CNC lathes.

Rules of Conduct

1. Absolutely no horseplay or practical joking will be tolerated.
2. Do not talk to anyone who is operating a machine.
3. Walk only in the designated traffic lanes.
4. Dress appropriately; at the absolute minimum, you must have:
   a. No loose clothing, including ties;
   b. Long hair properly stowed;
   c. No jewelry;
   d. Hard, closed-toe shoes;
   e. Eye protection (safety glasses); and,
   f. Ear protection (plugs or headset).
5. Follow all institutional safety rules.

To The Employer

This program requires that all students share in the responsibility for their own vocational development. Our objective is to help learners assume responsibility while acquiring the skills needed to enter productive wage-earning employment. Instruction is competency-based, and students are evaluated on how well they can perform specific skills.

The competencies and specific skills were prepared by a group of expert workers from the occupational field. A "5" rating reflects the degree of competence normally associated with a skilled person with two or more years of experience. The student completing this program of instruction is expected to have the majority of ratings at the "4" and "3" levels. Skills without ratings indicate that the student chose not to study the skill or that the occupational area of specialization did not require that skill. Only skills mastered by the student will be rated by the instructor.

Employers are asked to review these skill ratings periodically so that both the employer and the employee will have an ongoing awareness of the employee's development needs.

Employers may find the Record Of Achievement useful in planning for promotions, assignments, and additional training.

____
Program Director

____
Date

To The Instructor

Instructors are requested to authenticate the degree of mastery achieved by the student by writing the number of the level of achievement in the oval in the task box and initialling in the rectangle in the task box every time the student masters a competency. Later, if a student achieves a higher degree of mastery there may be a second, and possibly a third, authentication by the instructor.

Instructors are also requested to indicate below their full name and school address.

Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization
Authentication Initials	Signature	Organization

MASTER

Machine Tool Advanced Skills Technology Educational Resources Program

Certificate of Competency

This is to certify that

has satisfactorily completed the
required competencies acknowledged on the reverse side for the program of

CONVENTIONAL MACHINING

and is hereby granted this certificate

This_________ day of____________________ 19______

______________________ Director

______________________ Instructor

CONVENTIONAL MACHINING

Performance Levels	
5	Can perform this skill without supervision and with initiative and adaptability to problem situations.
4	Can perform this skill satisfactorily without assistance or supervision.
3	Can perform this skill satisfactorily but requires some assistance and/or supervision.
2	Can perform parts of this skill satisfactorily but requires considerable assistance and/or supervision.
1	Cannot perform this skill.

INSTRUCTOR WILL INITIAL LEVEL ACHIEVED FOR EACH COMPETENCY

Ratings on the chart are based on industrial performance standards. They are confirmed by an instructor (a skilled and experienced person from this occupation) who views and evaluates performance as he would in the role of an employer or supervisor.

A letter of reference attesting to the individual's attendance, punctuality, and work habits, is available from the certifying organization.

DUTIES	TASKS											
PREPARE FOR EMPLOYMENT	DISCOVER LEADERSHIP ELEMENTS	SPEAK TO GROUPS	MAKE DECISIONS	SELECT JOB PROFILES	PREPARE FOR THE WORLD OF WORK							
PRACTICE SAFETY	FOLLOW SAFETY MANUALS AND ALL SAFETY REGULATIONS/ REQUIREMENTS	USE PROTECTIVE EQUIPMENT	FOLLOW SAFE OPERATING PROCEDURES FOR HAND AND MACHINE TOOLS	MAINTAIN A CLEAN AND SAFE WORK ENVIRONMENT	MSDS/CONTROL CHEMICAL HAZARDS	LIFT SAFELY	IDENTIFY/ CONTROL FIRE HAZARDS					
APPLY MATHEMATICAL CONCEPTS	PERFORM BASIC ARITHMETIC FUNCTIONS	CONVERT FRACTIONS/ DECIMALS	CONVERT METRIC/ENGLISH MEASUREMENTS	PERFORM BASIC ALGEBRAIC OPERATIONS	USE PRACTICAL GEOMETRY	UNDERSTAND BASIC TRIGONOMETRY	USE COORDINATE SYSTEMS	CALCULATE SPEEDS AND FEEDS FOR MACHINING	PERFORM CALCULATIONS FOR SINE BAR AND SINE PLATE	CALCULATE FOR DIRECT, SIMPLE, AND ANGULAR INDEXING	PERFORM CALCULATIONS NECESSARY FOR TURNING TAPERS	CALCULATE DEPTH OF CUT FOR ROUND SURFACES
INTERPRET ENGINEERING DRAWINGS AND CONTROL DOCUMENTS	IDENTIFY BASIC LAYOUT OF DRAWINGS	IDENTIFY BASIC TYPES OF DRAWINGS	REVIEW BLUEPRINT NOTES AND DIMENSIONS	LIST THE PURPOSE OF EACH TYPE OF DRAWING	VERIFY DRAWING ELEMENTS	PRACTICE GEOMETRIC DIMENSIONING AND TOLERANCING (GD&T)	ANALYZE BILL OF MATERIALS (BOM)	SKETCH TOOL DIAGRAMS				
RECOGNIZE DIFFERENT MANUFACTURING MATERIALS AND PROCESSES	IDENTIFY MATERIALS WITH DESIRED PROPERTIES	IDENTIFY MATERIALS AND PROCESSES TO PRODUCE A PART	DESCRIBE THE HEAT TREATING PROCESS	TEST METAL SAMPLES FOR HARDNESS	UNDERSTAND WELDING OPERATIONS	EVALUATE ALTERNATIVE PROCESSES	INVESTIGATE BASIC METALLURGY					
MEASURE/ INSPECT	UNDERSTAND METROLOGY TERMS	SELECT MEASUREMENT TOOLS	ELIMINATE MEASUREMENT VARIABLES	MEASURE WITH HAND HELD INSTRUMENTS	MEASURE/ INSPECT USING SURFACE PLATE AND ACCESSORIES	INSPECT USING STATIONARY EQUIPMENT						
PERFORM CONVENTIONAL MACHINING	PREPARE AND PLAN FOR MACHINING OPERATIONS	USE HAND TOOLS	OPERATE POWER SAWS	OPERATE DRILL PRESSES	OPERATE VERTICAL MILLING MACHINES	OPERATE HORIZONTAL MILLING MACHINES	OPERATE METAL CUTTING LATHES	OPERATE GRINDING/ ABRASIVE MACHINES				
PERFORM ADVANCED MACHINING	PREPARE AND PLAN FOR CNC MACHINING OPERATIONS	SELECT AND USE CNC TOOLING SYSTEMS	PROGRAM CNC MACHINES	OPERATE CNC MACHINING CENTERS (MILLS)	OPERATE CNC TURNING CENTERS (LATHES)	PROGRAM CNC MACHINES USING A CAM SYSTEM	DOWNLOAD PROGRAMS VIA NETWORK					
IMPLEMENT QUALITY ASSURANCE PROGRAMS	DESCRIBE THE RELATIONSHIP OF ENGINEERING DRAWINGS TO PLANNING	UNDERSTAND AND USE QUALITY SYSTEMS	USE STANDARDS TO VERIFY REQUIREMENTS									
UTILIZE COMPUTER SYSTEM	RECOGNIZE/USE OPERATING SYSTEM	USE INQUIRY SYSTEMS	INVESTIGATE BASIC CAD SYSTEMS									

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